Lincoln's Sparrow (*Melospiza lincolnii*): A Technical Conservation Assessment

Prepared for the USDA Forest Service,
Rocky Mountain Region,
Species Conservation Project

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COVER PHOTO CREDIT

Lincoln's sparrow (*Melospiza lincolnii*). Western, U.S. © Don DesJardin, photographer (http://birdsdesjardin.com). Used with his permission.

Summary of Key Components for Conservation of the Lincoln's Sparrow

The Nature Conservancy classifies the Lincoln's sparrow (*Melospiza lincolnii*) as G5, meaning the species' rangewide status is demonstrably secure, although it may be rare in parts of its range, especially at the periphery. Overgrazing is possibly the most substantive impact to Lincoln's sparrows in the U.S. Forest Service, Rocky Mountain Region (Region 2). Overgrazing decreases the volume of vegetation and alters hydrologic regimes, and it contributes to increased predation rates and lower abundances of Lincoln's sparrows. Recreation within subalpine zones of Region 2 forests can also have significant impacts to Lincoln's sparrows by causing nest abandonment and decreased reproductive success. Habitat loss due to urbanization is another threat to Lincoln's sparrows in Region 2. Rudzitis and Johansen (1989) have documented that those sparrow populations in counties that contain or are adjacent to federally designated wilderness areas grew two to three times faster than those in all other counties in the country beginning in the 1970s. Other threats to this species are the loss of habitat on breeding, migration, and wintering grounds; pesticide use in the winter range; mining; and collisions with television towers during migration. Lincoln's sparrows should benefit from the regulation of livestock grazing in riparian wetlands and minimizing the impacts of recreation in riparian areas of subalpine zones, where the greatest breeding densities of Lincoln's sparrows occur. Additionally, conservation of nesting habitat, migratory stop-over habitat, and wintering habitat should benefit the species.

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INTRODUCTION

This assessment is one of many being produced to support the Species Conservation Project for the Rocky Mountain Region, U.S. Forest Service (USFS). The Lincoln's sparrow (*Melospiza lincolnii*) is the focus of an assessment because it is proposed to be a Management Indicator Species (MIS) for the Rio Grande National Forest (RGNF) (http://www.fs.fed.us/r2/riogrande/planning/planreversal.html). Management Indicator Species serve as barometers for species viability at the forest level and have two functions: 1) to estimate the effects of planning alternatives on fish and wildlife populations (36 CFR 219.19 (a)(1)); and 2) to monitor the effects of management on species via changes in populations trends (36 CFR 219.19 (a)(6)). The Lincoln's sparrow is associated with riparian-willow (*Salix* spp.) communities at various elevations. As such, it is susceptible to grazing and other activities within riparian areas, which is why it has been proposed to be a MIS.

This assessment addresses the biology of the Lincoln's sparrow throughout its range in the Rocky Mountain Region, or Region 2. The broad nature of the assessment leads to some constraints on the specificity of information for particular locales. This introduction defines the goal of the assessment, outlines its scope, and describes the process used in its production.

Goal

Species conservation assessments produced as part of the Species Conservation Project are designed to provide forest managers, research biologists, and the public a thorough discussion of the biology, ecology, conservation status, and management of certain species based on scientific knowledge accumulated prior to initiating the assessment. The assessment goals limit the scope of the work to critical summaries of scientific knowledge, discussions of broad implications of that knowledge, and outlines of information needs. The assessment does not seek to develop specific management recommendations but provides the ecological background upon which management must be based. However, it does focus on the consequences of changes in the environment that result from management (i.e. management implications) that will be used by managers to direct land management decisions. Furthermore, it cites management recommendations proposed elsewhere, and when management recommendations have been implemented, the assessment examines the success of that implementation.

Scope

The Lincoln's sparrow assessment examines the biology, ecology, conservation status, and management of this species with specific reference to the geographic and ecological characteristics of the USFS, Rocky Mountain Region. Although a majority of the literature on this species originates from field investigations outside the region, this document places that literature in the ecological and social context of the central Rocky Mountains. Similarly, this assessment is concerned with reproductive behavior, population dynamics, and other characteristics of Lincoln's sparrows in the context of the current environment rather than under historical conditions. The evolutionary environment of the species is considered in conducting the synthesis, but it is placed in a current context.

In producing the assessment, we reviewed refereed literature, non-refereed publications, research reports, and data accumulated by resource management agencies. Not all publications on Lincoln's sparrows are referenced in the assessment, nor was all published material considered equally reliable. The assessment emphasizes refereed literature because this is the accepted standard in science. Non-refereed publications or reports were regarded with greater skepticism and used only when information was unavailable elsewhere. Unpublished data (e.g. Natural Heritage Program records) were important in estimating the geographic distribution. These data required special attention because of the diversity of persons and methods used to collect the data. . An important limitation of this assessment is its applicability to areas beyond where the data were collected. While some characteristics remain similar throughout the Lincoln's sparrow's range, community assemblages become increasingly different as the distance between sites increases. Therefore, the ability to predict the response of Lincoln's sparrows to various factors becomes increasingly difficult and uncertain as the distance between inference communities increases. An additional limitation of this assessment is that the Lincoln's sparrow is a poorly studied species, and there are many gaps in our knowledge of the species.

Treatment of Uncertainty

Science represents a rigorous, systematic approach to obtaining knowledge. Competing ideas regarding how the world works are measured against observations. However, because our descriptions of the world are always incomplete and our observations are limited, science focuses on approaches for dealing with uncertainty. A commonly accepted approach to science is

based on a progression of critical experiments to develop strong inference (Platt 1964). However, it is difficult to conduct critical experiments in the ecological sciences, and often observations, inference, good thinking, and models must be relied on to guide the understanding of ecological relations. In this assessment, the strength of evidence for particular ideas is noted, and alternative explanations are described when appropriate. While well-executed experiments represent a strong approach to developing knowledge, alternative approaches such as modeling, critical assessment of observations, and inference are accepted as sound approaches to understanding features of biology. More specifically, when dealing with uncertainty in this assessment, we always noted when inferences were made, and when the strength of evidence for particular ideas was not certain, we used phrases such as '…is likely to…', '…is probable that…', '…might be…', etc.

Application and Interpretation Limits of this Assessment

Most of the data presented in this assessment are from site-specific studies. An important limitation of this assessment is its applicability to areas beyond where the data were collected. While some characteristics remain similar throughout the species' range, community assemblages become increasingly different as the distance between sites increases. Therefore, the ability to predict the response of Lincoln's sparrows to various factors becomes increasingly difficult and uncertain as the distance between inference communities increases, and the information should be interpreted and applied generally, with conservation plans being developed by inference.

Publication of Assessment on the World Wide Web

To facilitate use of species assessments in the Species Conservation Project, assessments are being published on the USFS Region 2 World Wide Web site. Placing the documents on the Web makes them available to agency biologists and the public more rapidly than publishing them as reports. More important, it facilitates revision of the assessments, which will be accomplished based on guidelines established by Region 2.

Peer Review

Assessments developed for the Species Conservation Process have been peer reviewed prior to release on the Web. This report was reviewed through a process administered by the Society for Conservation Biology which chose two recognized experts to provide critical input on the manuscript. Peer review was designed to improve the quality of communication and increase the rigor of the assessment.

MANAGEMENT STATUS AND NATURAL HISTORY

Management Status

The Natural Heritage Program's global rank for the Lincoln's sparrow is G5. The Natural Heritage Program's state rank in Wyoming is S5B and S5N; Colorado is S5B and SZN; South Dakota is SZN, Nebraska is S?N; Kansas is S3N (**Figure 1**; **Table 1**). The U.S. Fish and Wildlife Service does not classify the Lincoln's sparrow with any special management status. In USFS Region 2, the species is not designated as sensitive, and the RGNF is the only forest currently proposing to list the Lincoln's sparrow as a MIS.

Existing Legal Mechanisms, Management Plans, and Conservation Strategies

The only conservation strategy specific to the Lincoln's sparrow of which we are aware is that the RGNF has proposed to classify this bird as a MIS. As such, it will serve as a barometer of the effects of forest management activities on wildlife species tied to the riparian-willow communities where Lincoln's sparrows occur. For Wyoming, The Wyoming Bird Conservation Plan recommends conservation actions for the riparian habitats where this sparrow occurs (Cerovski et al. 2001).

We did not find any other existing legal mechanisms, management plans, or conservation strategies specifically for the Lincoln's sparrow. However, the Lincoln's sparrow is protected by several laws that broadly apply to many wildlife species including the Migratory Bird Treaty Act of 1918, National Forest Management Act of 1976, and the Neotropical Migratory Bird Conservation Act of 2000. It appears that these regulations are adequate to conserve Lincoln's sparrows at present, as the species is stable throughout its range.

The Migratory Bird Treaty Act of 1918 established a federal prohibition, unless permitted by regulations, to "pursue, hunt, take, capture, kill, attempt to take, capture or kill, possess, offer for sale, sell, offer to purchase, purchase, deliver for shipment, ship, cause to

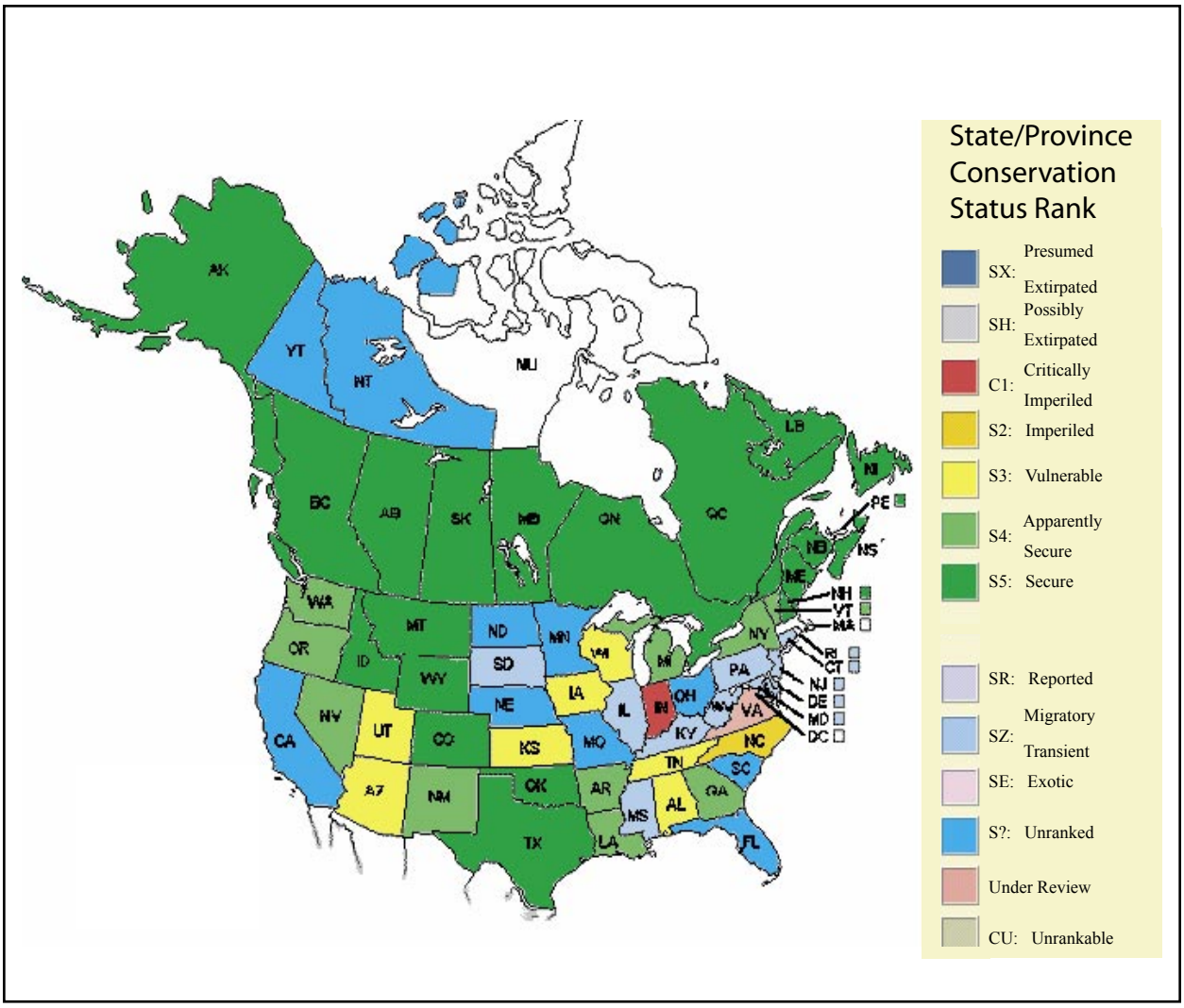


Figure 1. Status of Lincoln's sparrows in North America based on the Natural Heritage Program (NatureServe Explorer 2001).

Table 1. Status of the Lincoln's sparrow based on the Natural Heritage Program rankings (NatureServe Explorer 2001).

State	**TNC State Rank**	
	Breeding Season	Non-breeding Season
Colorado	S5	SZ
Wyoming	S5	S5
South Dakota	Not Applicable	SZ
Nebraska	Not Applicable	S?
Kansas	Not Applicable	S3

SZ – Taxa that is not of significant concern in a state.

S5 – Demonstrably secure in state, although the species may be rare in parts of its range, especially at the periphery.

S3 – Rare or local throughout its range or found locally in a restricted range (usually known from 21 to 100 occurrences) in state.

S? – Questions exist regarding the assigned state rank.

be shipped, deliver for transportation, transport, cause to be transported, carry, or cause to be carried by any means whatever, receive for shipment, transportation or carriage, or export, at any time, or in any manner, any migratory bird, included in the terms of this Convention . . . for the protection of migratory birds . . . or any part, nest, or egg of any such bird." (16 U.S.C. 703; http: //laws.fws.gov/lawsdigest/migtrea.html). Additionally, treaties formed as a result of the Migratory Bird Treaty Act of 1918 obligate the federal government to take measures to protect identified ecosystems of special importance to migratory birds against pollution, detrimental alterations, and other environmental degradations.

The National Forest Management Act of 1976 stipulates that the USFS must " provide for multiple use and sustained yield of the products and services obtained there from in accordance with the Multiple-Use, Sustained-Yield Act of 1960, and in particular, include coordination of outdoor recreation, range, timber, watershed, wildlife and fish, and wilderness" (http://www.fs.fed.us/forum/nepa/nfmalaw.html).

The Neotropical Bird Conservation Act of 2000 provides grants to countries in Latin America and the Caribbean, and to the United States for the conservation of neotropical migratory birds that winter south of the U.S. border and summer in North America. The law encourages habitat protection, education, researching, monitoring, and capacity building to provide for the long-term protection of neotropical migratory birds (http://laws.fws.gov/lawsdigest/neotrop.html).

Loosely related to conservation strategies, several monitoring programs are used to collect information on population trends of many bird species, including the Lincoln's sparrow. These programs include the North American Breeding Bird Survey (BBS), Monitoring of Avian Productivity and Survivorship (MAPS) Program, and Monitoring Colorado's Birds.

The BBS is a large-scale survey of North American birds (http://www.mbr-pwrc.usgs.gov/bbs/intro00.html). It is a roadside survey, primarily covering the continental United States and southern Canada, although survey routes have recently been initiated in Alaska and northern Mexico. The BBS was started in 1966, and over 3,500 routes are surveyed in June by experienced birders . The primary objective of the BBS has been the estimation of population change for songbirds. However, the data have many potential uses, and investigators have used the data to address a variety of research and management objectives.

MAPS was created by The Institute for Bird Populations in 1989 to assess and monitor the vital rates and population dynamics of over 120 species of North American landbirds in order to provide critical conservation and management information on their populations (http://www.birdpop.org/maps.htm). The MAPS Program utilizes constant-effort mist netting and banding through a continent-wide network of monitoring stations staffed by both professional biologists and highly trained volunteers. MAPS is organized around research and management goals as well as monitoring goals. MAPS data are used to describe temporal and spatial patterns in the vital rates of target species, and the relationships between these patterns and (1) ecological characteristics and population trends of the target species, (2) station-specific and landscape-level habitat characteristics, and (3) spatially explicit weather variables. Information from these patterns and relationships are then used to identify the causes of population declines, to formulate management actions and conservation strategies to reverse declines, and maintain healthy populations, and to evaluate the effectiveness of management actions and conservation strategies.

The Monitoring Colorado's Birds project focuses on obtaining count-based data for all breeding bird species in the state on a randomly allocated and habitat-stratified basis. Leukering et al. (2000) summarized the methods and future objectives for this project. Three methods are used (transects, colony counts, and censussing) to obtain population data for Colorado's breeding-bird species, with transects being the primary method. Transects (15 point counts/ transect) are performed in 30 randomly selected stands in each of the 14 habitats monitored. Standard distance-sampling techniques are used during all transect surveys, and density estimates of bird species are derived using program DISTANCE (Thomas et al. 1998).

Biology and Ecology

Systematics and description

Lincoln's sparrows are in the Order: Passeriformes; Family: Emberizidae. Three subspecies have been described: *Melospiza lincolnii lincolnii*, *M. l. gracilis*, and *M. l. alticola* (Ammon 1995a). These subspecies are differentiated by geographic distribution, size, and coloration of dorsal feathers.

The breeding distribution of *Melospiza lincolnii alticola* is in the southern montane area of North

America including the central Rocky Mountains south of Canada into Arizona and New Mexico, and also in parts of California and Oregon (Miller and McCabe 1935). It is the largest subspecies, with males and females having an average wing length of 65.2 mm and 61.5 mm, respectively (Miller and McCabe 1935). The dorsal feathers of *M. l. alticola* are mostly brown with narrow shaft streaks on dorsal feathers, thus appearing more uniform in color than other subspecies (Ammon 1995a).

The breeding distribution of *Melospiza lincolnii lincolnii* is the transcontinental boreal area of North America from Alaska to Newfoundland (Miller and McCabe 1935). Even though this subspecies is slightly smaller than *M. l. alticola*, there are considerable overlaps in size and color of their dorsal feathers. Therefore, some authors suggest considering them as one subspecies (Phillips et al. 1964).

The breeding distribution of *Melospiza lincolnii gracilis* is the northern Pacific coast area from the southern Alaskan archipelago to central British Columbia. It is the smallest subspecies, with males and females having an average wing length of 60.6 mm and 58.0 mm, respectively (Miller and McCabe 1935). The dorsal feathers of *M. l. gracilis* are generally more yellow and have broader dark shaft streaks, thus greater contrasts in dorsal coloration than the other subspecies (Ammon 1995a).

Based on morphological and genetic evidence, the most closely related species to Lincoln's sparrows are swamp sparrows (*Melospiza georgianna*) and song sparrows (*M. melodia*) (Zink 1982). In fact, differentiation of juvenile Lincoln's and swamp sparrows is impossible on the basis of qualitative plumage differences (Rimmer 1986). Birds need to be in the hand for a positive identification. In Lincoln's sparrows, the 9th primary is longer than the 4th, while the 9th primary is shorter than the 4th in swamp sparrows (Rimmer 1986).

Lincoln's sparrows are small and sexually monomorphic in plumage (Ammon 1995a). They have a buffy wash and fine streaks on the breast and sides, contrasting with a whitish, unstreaked belly (National Geographic Society 1999). Diagnostic characteristics of the head include a broad gray eyebrow, whitish chin and eye ring (National Geographic Society 1999). As described above, males are larger than females, but this is not diagnostic due to overlaps in size. Other than brood patches on breeding females and cloacal protuberances on breeding males, we are unaware of any other methods to distinguish the sexes. They are usually solitary, highly secretive, and are most easily distinguished from other sparrows by their rich, wren-like song (Ammon 1995a).

Distribution and abundance

Breeding distribution

As a long-distance migrant, the distribution of the Lincoln's sparrow covers a vast area in North and Central America (**Figure 2**). The breeding range extends throughout most of Alaska and Canada, southwards into mountainous areas along the Pacific coast in Washington, Oregon, and California, and southwards through the Rocky Mountains in Idaho, Montana, Utah, Wyoming, Colorado, Arizona, and New Mexico wherever suitable boreal habitat exists. In Wyoming, the Lincoln's sparrow is a common summer resident in riparian shrub habitats above 2,200 m (Luce et al. 1999). They breed throughout most of the state, except the far eastern side (Luce et al. 1999). In Colorado, the Lincoln's sparrow is fairly common during both the breeding season and migration (Kingery and Graul 1978).

Even though historical changes in the distribution boundaries of the Lincoln's sparrow are unknown, it is likely that their distribution decreased with the arrival of Europeans to North America. It is difficult to estimate changes to the range of Lincoln's sparrows in North America between 1780's and now since (1) quantitative information on wetlands is not available from early engineering or reconnaissance survey reports, and (2) political boundaries, and in some instances, geographical boundaries have changed dramatically since the 1780's (Dahl 1990). For this assessment, we are limited to using estimates of historical wetland losses and making inferences to the riparian-willow habitats inhabited by Lincoln's sparrows in Region 2. Dahl (1990) estimates that over a period of 200 years, the lower 48 states lost an estimated 53% of their original wetlands. Between the 1780's and the 1980's, it is estimated that Wyoming, Colorado, South Dakota, Nebraska, and Kansas lost 38%, 50%, 35%, 35%, and 48% of their wetlands, respectively (Dahl 1990). Agriculture and urban expansion account for the majority of conversions from wetland to upland (Dahl and Johnson 1991). Even though information on the differences between current and historical distributions specific to Lincoln's sparrow habitat is scant, other evidence indicates that their habitat has decreased along with the arrival of Europeans to North America (McKinstry et al. 2001). Beaver, a keystone species that promotes the development of shrubby riparian habitat, have been extirpated from 23% of the streams in Wyoming

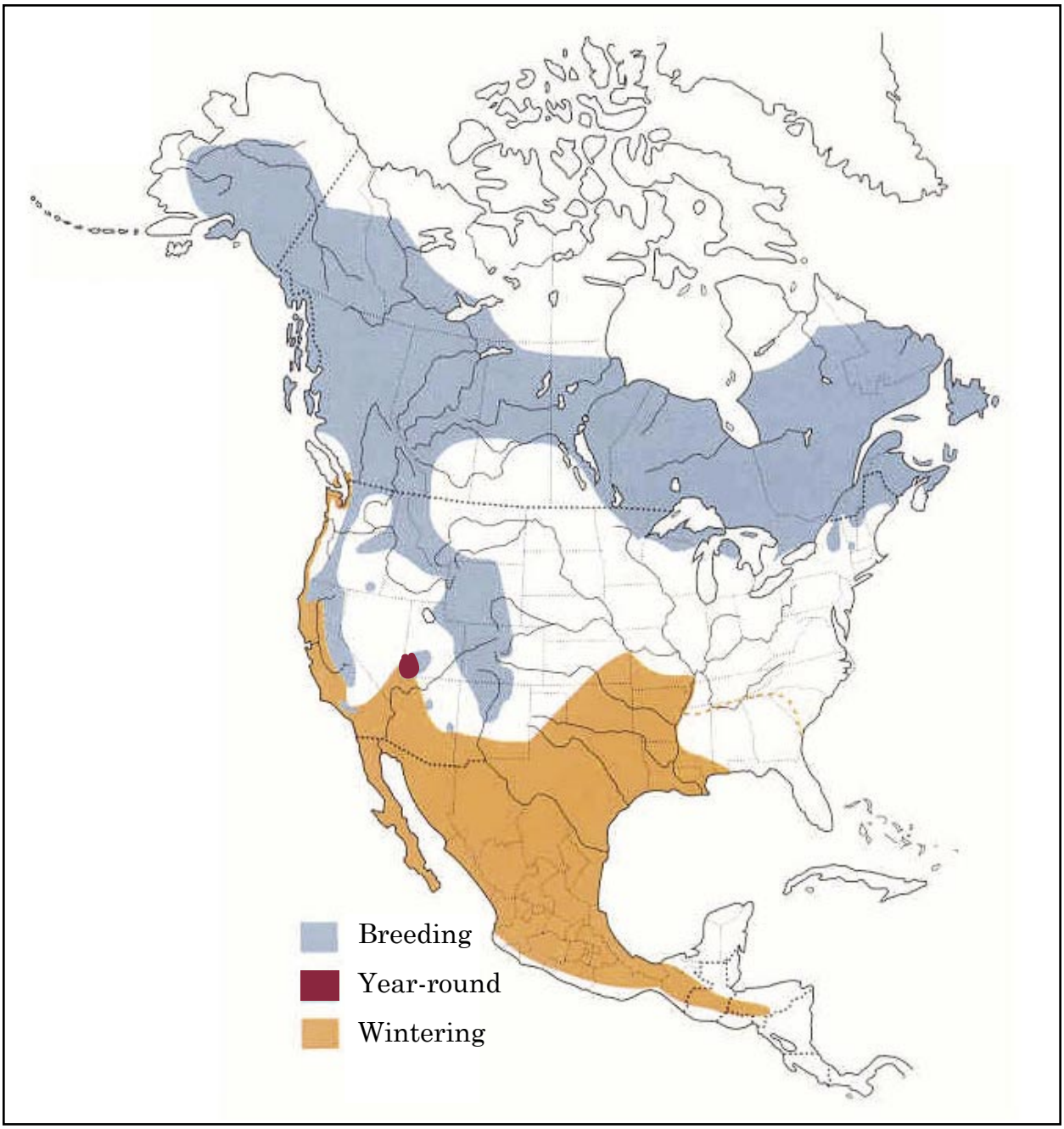


Figure 2. Distribution of the Lincoln's sparrow (Ammon 1995a).

(McKinstry et al. 2001). A reasonable inference can be drawn that with the loss of the beaver, riparian areas have also diminished, resulting in less habitat available for Lincoln's sparrows in their breeding range.

Distribution during non-breeding season

The winter range extends from southwest British Columbia southalong the Pacific coast of Washington and Oregon, and through western and southeastern California to southern Baja California. East of California, the winter range covers parts of Nevada, Utah, Arizona, New Mexico, Texas, Oklahoma, Kansas, Missouri, Arkansas, Louisiana, Mississippi, and Alabama. This species also winters in Mexico, Guatemala, El Salvador, and Honduras.

In South Dakota, the Lincoln's sparrow is considered an uncommon (5 to 10 seen per day) to fairly common (0 to 15 seen per day) migrant (South Dakota

Ornithologists' Union 1991). Lincoln's sparrows have been observed in South Dakota as late as 16 December (Stukel and Stukel 1995). The Lincoln's sparrow is a common regular spring and fall migrant in eastern Nebraska, becoming uncommon to the west, and a rare casual winter visitor in the southeast part of the state (Sharpe et al. 2001). In Kansas, it is a common transient statewide with small numbers that regularly winter in the eastern and southeaste (Thompson and Ely 1992).

Abundance

The BBS and the Audubon Christmas Bird Count (CBC) provide estimates of Lincoln's sparrow abundance in most of North America during the breeding season (**Figure 3**) and the winter (**Figure 4**), respectively. Large variation of breeding density occurs throughout their geographical range, from <0.002 individuals/ha in the Maritime Provinces to 6 to 9 pairs/ha in the Colorado Front Range (Ammon 1995a). Large variation of breeding density also occurs at a smaller scale. Within a 5-km^2 study area in Colorado, there was a threefold difference in pair density (0.5 to 1.4 pairs/ha) between two sites (Wortman-Wunder 1997). Factors determining densities of Lincoln's sparrows are unclear.

Population trend

When interpreting Lincoln's sparrow trends, an important consideration is that population fluctuation is a normal characteristic of this species. Population fluctuations can be caused by many factors: excessive rainfall, extreme drought, changes in available habitat structure and quantity, and effects of natural disturbances such as insect outbreaks and fire (Rotenberry et al. 1992, cited in Finch and Yong 1996).

The BBS estimates that Lincoln's sparrows increased 2.26% (P=0.01) per year between 1966 and 2000 throughout the entire survey area (**Figure 5**; Sauer et al. 2001). In Wyoming (+14.64%; P=0.14) and Colorado (+1.06%; P=0.57), the BBS did not provide strong evidence for a trend (**Table 2**). No information was available for South Dakota, Nebraska, or Kansas. It is important to note that BBS estimates tend to be uncertain due to small sample sizes and problems

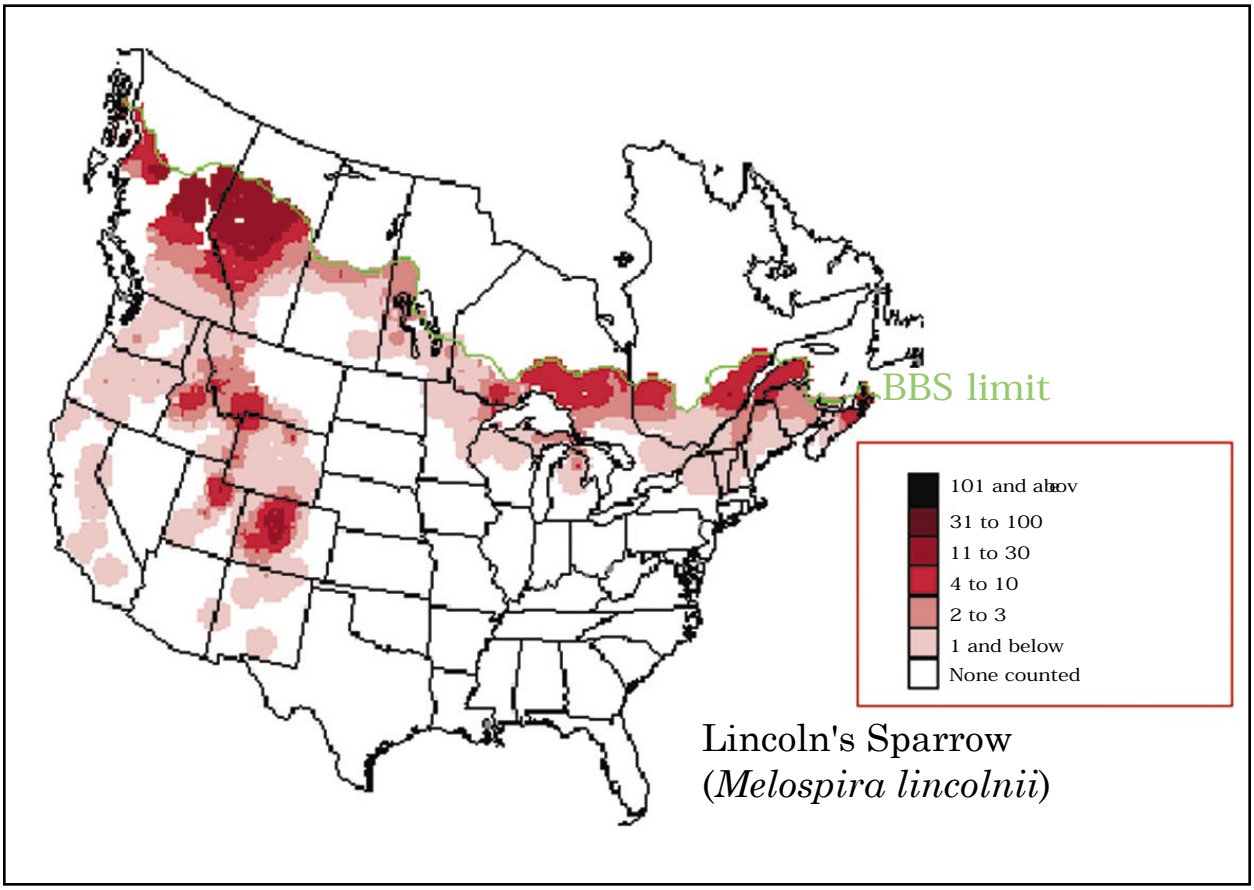


Figure 3. Summer distribution and abundance of Lincoln's sparrow in North America, based on the Breeding Bird Survey (Sauer et al. 2001).

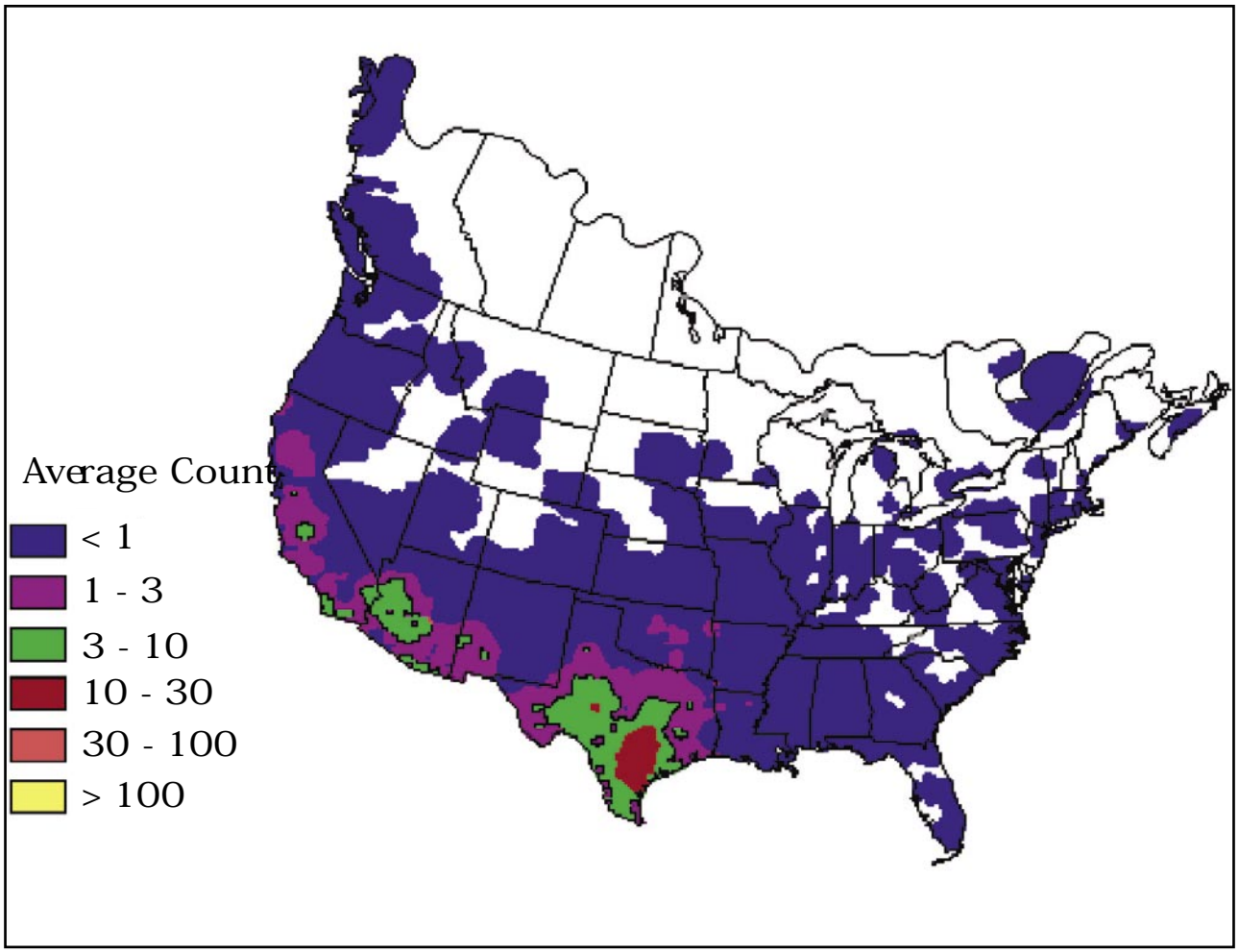


Figure 4. Winter distribution and abundance of Lincoln's sparrow in North America, based on the Audubon Christmas Bird Count (Sauer et al. 2001).

with survey design. Between 1959 and 1988, the CBC did not detect a trend (-0.84.... 0.6) (Sauer et al. 1996). Problems also exist with the CBC due to a non-randomized survey design and differences in observer expertise, which can affect the data and interpretation. Finch and Yong (1996) reported a positive population trend for Lincoln's sparrows from 1985 to 1994 during fall migration along the Rio Grande River in New Mexico. We are unaware of other quantitative measures of population trend for Lincoln's sparrow in Region 2 or neighboring areas.

Activity pattern and movements

Breeding season

During the breeding season, Lincoln's sparrows (males only) vocalize most frequently in early morning (starting at first light), with singing activity declining or ceasing during midday, and occurring moderately from late afternoon to sunset (Ammon 1995a). During the incubation period, females spend approximately 75% of their time on the nest (Speirs and Andoff 1958). Females spend the night on the nest during incubation and nestling stage (Ammon 1995a). It is unknown if the male engages in night brooding. Microsites of night roosts of males and non-breeding birds are undocumented, but breeding birds usually stay with their territory (Ammon 1995a).

Migration

All populations migrate and generally migrate at night (Ammon 1995a). Sex differences in migration times and routes, as well as subspecies-level variation in migration times are undocumented (Ammon 1995a). In most locations, spring migration begins mid- to late April, peaks in May, and ends in late May. Departure from breeding grounds usually begins in early September (Ammon 1995a). The fall migration peaks

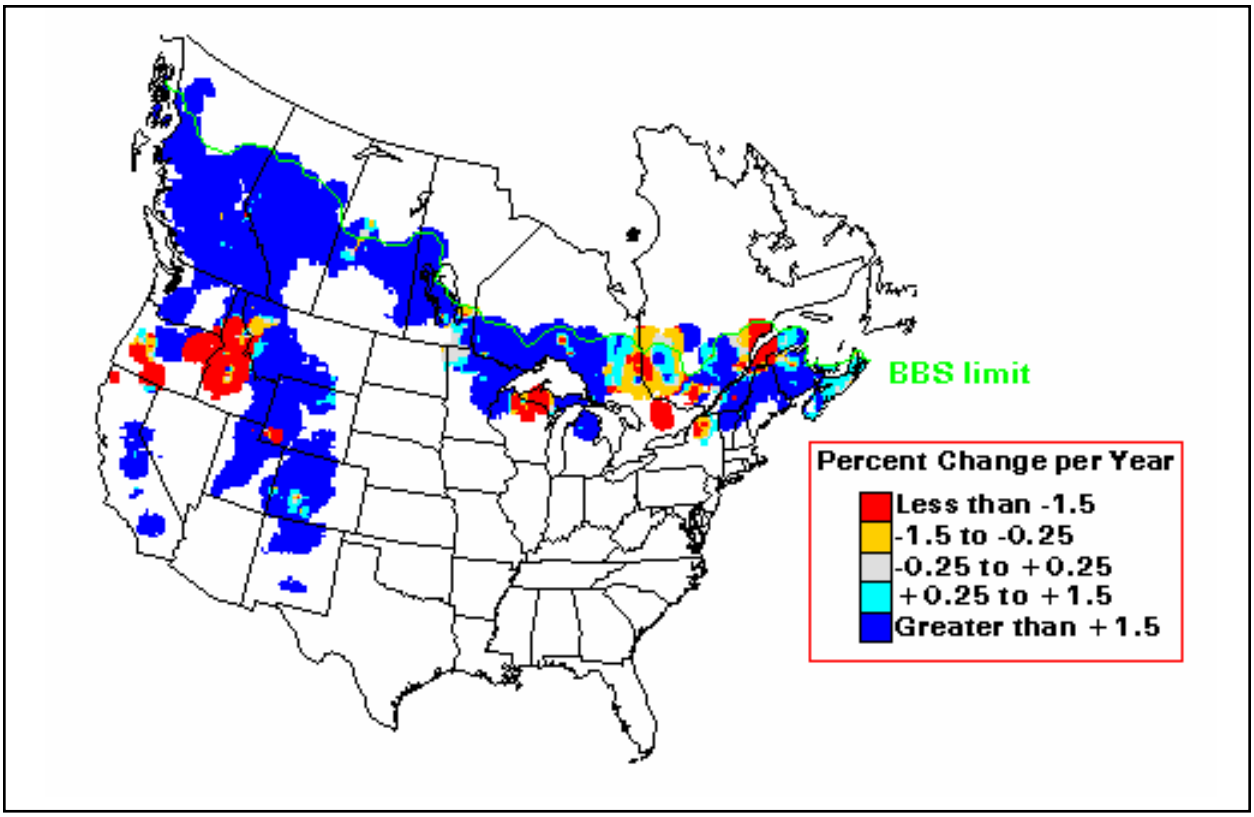


Figure 5. Trend map of the Lincoln's sparrow, based on Breeding Bird Survey (Sauer et al. 2001).

Table 2. Estimates of population trend for Lincoln's sparrows based on the Breeding Bird Survey (Sauer et al. 2001).

	% Annual Change (1966-2000)	p Value	N Routes [a]	Variance	Average Count [b]
Entire Survey Area	2.26	0.01	449	0.84	2.65
Wyoming	14.64	0.14	24	90.14	0.92
Colorado	1.06	0.57	44	3.41	7.03

[a] = routes where Lincoln's sparrows were detected for at least 2 years by the same observer.

[b] = average count/route of routes within the Lincoln's sparrows physiographic range.

from late September to early October and comes to an end between late October and early November (Ammon 1995a). In Colorado, Lincoln's sparrows start to return to lower elevations by late April and arrive at nest sites in the mountains in May (Kingery 1998). The timing of spring and fall migration for birds moving through South Dakota, Nebraska, and Kansas is similar; spring and fall migration occur from April through May, and September through October, respectively (South Dakota Ornithologists' Union 1991, Sharpe et al. 2001, Thompson and Ely 1992).

Dispersal

Banding data indicates that a higher percentage adults return to their breeding grounds between years than juveniles. In Colorado, the return rates of adult males and females to breeding grounds from year to year was 37% (n = 123) and 36%, respectively (n = 85; data from Colorado Bird Observatory [CBO] in Ammon 1995b). The return rates of young were much lower with only 2% of young returning to the natal site (n = 137; data from CBO in Ammon 1995b). These differences are likely due to lower survivorship of juveniles during migration and winter. No other mark-and-recapture studies with information on dispersal were found. However, Marshall (1988) reported that Lincoln's sparrows established populations in Tulare County, California between the 1930's and 1986 in newly created riparian habitat. The closest known populations of the 1930s' to the newly established populations in 1986 were approximately 2.5 km away.

An important issue concerning connectivity of Lincoln's sparrow habitat could be the connectivity of summer ranges to winter ranges. Many neotropical migrants use riparian corridors as flyways through arid landscapes because those areas supply suitable species-specific resources that may be lacking in the surrounding landscape (Johnson and Jones 1977, Finch et al. 1995). Although Lincoln's sparrows are not neotropical migrants, they migrate long distances through arid habitats in the western United States and would be expected to use habitats similar to those used by neotropical migrants. Many of these riparian, migratory corridors have been extensively modified by human activities such as urbanization and agriculture (Mitsch and Gosselink 2000). Alteration and loss of riparian habitats may negatively affect migratory species that breed and winter elsewhere by reducing the amount of suitable habitat where they can rest, find food, and replenish fat stores. The loss of such areas could increase the stresses upon migrants and reduce survivorship. However, the above-mentioned impacts are uncertain due to a dearth of dispersal data on the Lincoln's sparrow and their ability to fly great distances.

Habitat

A limitation of the information available on Lincoln's sparrow habitat use is that it is qualitatively described. Additionally, most of the habitat has been described at the 3rd Order (Johnson 1980) or 'fine scale'. Therefore, not much has been reported about habitat preference or selection of this sparrow at the broad scales.

Breeding habitat

What we know about broad scale habitat use is that the highest densities of nesting Lincoln's sparrows occur in relatively high-elevation riparian-willow habitats (approximately 1,500 to 3,400 m) throughout the western United States. These riparian-willow habitats are commonly surrounded by large, contiguous tracts of upland forest. Forest types include lodgepole pine (*Pinus contorta*), spruce (*Picea* spp.), fir (*Abies* spp.), and aspen and cottonwoods (*Populus* spp.). In Colorado, Lincoln's sparrows have a lower altitudinal limit at about 2,440 m, and nest sites are typically found in the subalpine and montane zones (Kingery 1998). In Wyoming, Finch (1989) investigated trends in bird species populations along a riparian altitudinal cline in the Medicine Bow National Forest. Streamside habitats were divided into three elevational zones: low-elevation (2,050 to 2,260 m) cottonwood zone; mid-elevation (2,290 to 2,530 m) mixed shrub willow zone; and high-elevation (2,590 to 2,990 m) subalpine willow zone. Lincoln's sparrows were much more common in the high-elevation zones (**Table 3**). These riparian zones tend to be narrow, linear features of the landscape often lining streams with steep gradients and narrow floodplains (Mitsch and Gosselink 2000). However, geological characteristics, soils, and the activity of beaver can lead to broad patches of habitat that occur in broad glacial valleys.

At finer spatial scales, breeding habitat for Lincoln's sparrows may be characterized as riparian shrub lands. They breed in boggy habitats where the dominant vegetation ranges from tamarack to willows or sedges (Kingery 1998). In the Front Range of Colorado, they use boggy, willow, sedge (*Carex* spp.), and moss-dominated habitats, particularly where shrub cover is dense (Ammon 1995a). A description the Lincoln's sparrows primary microhabitat by activity is low willows for nesting, ground and base of willows for foraging (foraging height mostly below 1 m, but up to 2 m; Cody 1974 in Ammon 1995b), and tall perch trees and exposed willow branches for singing (Ammon 1995b). Habitat in central Colorado was described as having equal percentages of three main vegetation types present: dense willow (1 to 3 m tall and too dense to walk through easily), open scattered shrub, and grass (Wortman-Wunder 1997). At another site in Colorado, Lincoln's sparrows selected for sites with (1) willows that were taller than those at random sites ($P < 0.01$), (2) willows with greater number of dead stems than occurred in randomly located bushes ($P = 0.00$-0.11), and (3) stands of bushes with lower mean distances between bushes ($P < 0.05$; Knopf et al. 1988). In

Table 3. Mean number of territorial pairs of Lincoln's sparrows/8.1 ha (± SE) in three riparian elevational zones in Medicine Bow National Forest, WY (Finch 1989).

Elevation	1982	1983	1984
Low (2050 to 2260 m)	0.3 ± 0.6	0.3 ± 0.6	0.3 ± 0.6
Middle (2290 to 2530 m)	4.0 ± 1.3	10.3 ± 1.6	11.0 ±1.7
High (2590 to 2990 m)	20.0 ± 1.5	16.0 ± 1.1	15.5 ± 0.6

California and Oregon, important habitat characteristics were identified as wet meadows with willows, corn lily (*Veratrum* spp.), and pines (especially *Pinus contorta*) present (Cicero 1997). Pine trees along the edges of meadows were commonly used as perch sites for singing and vigilance.

Nest sites

Nests are always on the ground, most often inside a low willow shrub or mountain birch (*Betula glandulosa*) that also contains fairly dense sedge cover (Ammon 1995b). Nests are usually placed on elevated mounds around shrubs usually 60 cm or less in height. Nests are usually well concealed with a distinct nest entrance tunnel through ground vegetation, oriented toward east-northeast (Ammon 1995b). Aspen groves are also used as nesting sites with considerable frequency (Kingery 1998). In Colorado, nest sites in aspen stands occur on slopes with seeps, dense grass cover, and some shrubs (T. Leukering, Rocky Mountain Bird Observatory, personal communication).

Migratory habitat

During migration, Lincoln's sparrows, like other migratory songbirds, likely use riparian corridors as flyways through arid grasslands because those areas supply suitable species-specific resources that may be lacking in the surrounding landscape (Finch et al. 1995). In South Dakota, migrating Lincoln's sparrows are typically found in thickets and residential shrubbery (South Dakota Ornithologists' Union 1991). In Nebraska, they frequent dense brush and thickets, usually close to water (Sharpe et al. 2001). In Kansas, they occur most commonly in brushy habitats, especially riparian situations, and in brushy tangles in fields and woodlands (Thompson and Ely 1992).

Both small and large riparian patches present in vast expanses of xeric landscapes are important stopover points for migrating birds. In southeast Arizona, small isolated riparian patches hosted more avian species than riparian sites with greater size-connectivity (Skagen et al. 1998). This is counterintuitive to traditional insights from habitat fragmentation studies that defend the importance of large, continuous habitat patches but not of small, isolated patches. Additionally, the relative abundances of most migrating birds and the body condition of the captured birds did not differ relative to the size-connectivity of the sites (Skagen et al. 1998). Lincoln's sparrows use both small, isolated and large, contiguous riparian sites (Skagen et al. 1998).

Winter habitat

Winter habitat is poorly understood but is described as brushy areas, thickets, hedgerows, the understory of open woodlands, forest edges, clearings, and scrubby areas (American Ornithologists' Union 1998). In Mexico, winter habitat includes tropical evergreen forests, arid and humid pine (*Pinus*)-oak (*Quercus*) forests, tropical deciduous forests, Pacific swamp forests, and arid subtropical scrublands (Binford 1989).

Food habits

The Lincoln's sparrow is a ground-gleaning, omnivorous bird that requires low brushy openings (Bent 1968). They eat mostly insects and some vegetation during the breeding season with the proportion of vegetation, particularly seeds, in the diet increasing outside of the breeding season (Salt 1957, Raley and Anderson 1990). In Wyoming, 54 families of arthropods were identified in Lincoln's sparrow diets (Raley and Anderson 1990). Coleoptera, especially soldier beetles (*Cantharidae* spp.), was preferred over all other groups. Other arthropod resources found in greater proportions than expected based on availability were Diptera, Homoptera, Araneae, and Ephemeroptera, in descending order of importance (Raley and Anderson 1990). During Miller moth (*Euxoa auxiliaris*) outbreaks, the proportion of this prey item in the diet increases (Ammon 1995a). When foraging, the Lincoln's sparrow is slow and methodical. As a result, many of their prey items are characterized as more cryptic than the prey of ecologically similar species such as the Wilson's warbler (*Wilsonia pusilla*) (Raley and Anderson 1990). They also eat plant matter, primarily in the form of small seeds. In California, Lincoln's sparrows are known to consume pigweed (*Amaranthus* spp.), barley (*Hordeum vulgare*), sedge and rabbitgrass (*Polypogon* spp.) (Martin et al. 1961). In the plains of the United States, seeds eaten by Lincoln's sparrows include bristlegrass (*Setaria* spp.), pellitory (*Parietaria* spp.), panicgrass (*Panicum* spp.), and corn (*Zea mays*) (Martin et al. 1961).

Breeding biology

In Colorado, Lincoln's sparrows arrive in the mountains in May to establish nest territories with all records of nest building occurring before mid-June (Kingery 1998). Males and females are known to be present at nests sites 10 to 14 days before nesting activity begins (Speirs and Speirs 1968). Males start singing as soon as they arrive on the breeding grounds. Singing practically ceases during the incubation period, except

for a few songs early in the morning, then increases again greatly when the young are about to leave the nest (Speirs and Speirs 1968). Lincoln's sparrows lay from three to six eggs, with four or five being more the norm (Speirs and Speirs 1968).

The courtship behavior of Lincoln's sparrows in Ontario, which occurred from 28 May to 5 June, has been described in detail (Speirs and Speirs 1968). Nest building activities occurred chiefly in mid-morning from 8:00 to 10:30 a.m. In most cases the female appeared to invite copulation by crouching, fluttering her wings, and uttering an excited, high-pitched note. The male then flew towards the female, appeared to 'pounce' on her, and copulation occurred.

Another study in Ontario reported on the timing of reproduction (Speirs and Andoff 1958). An active Lincoln's sparrow nest was found on 31 May. On the morning of 1 June the first egg was laid, and the fourth and final egg was laid before the morning of 4 June. During incubation, the attentive periods during the day averaged 20.4 minutes, while the inattentive periods averaged 6.9 minutes. On 16 June the first egg hatched and the final three eggs all hatched by mid-day on 17 June. Thus, the incubation period was determined to be 13 days. The young first leave the nest after approximately nine days post-hatch, which was between 26 June and 2 July in Ontario (Speirs and Speirs 1968). The young likely remain around the nest until at least 27 days of age. Some pairs might produce a second clutch, but it is probably uncommon (Speirs and Speirs 1968).

Lincoln's sparrows benefit from undisturbed nest sites. Significantly higher nest desertion rates occurred in three sites used by recreational visitors for picknicking, fishing, and hiking, compared to three sites not used for recreation in the Colorado Front Range (17.5% nests, $n = 40$, in visited sites, vs. 4% nests, $n = 48$, in unvisited sites; $P = 0.0398$; Ammon 1995b).

Demography

Genetics

As mentioned previously, landscapes in the western United States where Lincoln's sparrows nest form ecological islands separated from other suitable habitat by unoccupied coniferous forests. Due to the Lincoln's sparrows ability to fly great distances though, it is unlikely that genetic isolation poses a problem. However, no direct evidence regarding genetic structure of the species is available, so firm conclusions about the potential demographic consequences of genetic factors are not possible.

Survivorship

Average and maximum adult survivorship generally are unknown, but Lincoln's sparrows can reach at least seven years and four months of age, as determined from cohorts in a central Colorado population (data from CBO in Ammon 1995b). Adult mortality is low during the breeding season. During a four year study, Ammon (1995b) reported that only two birds of 196 pairs died during the breeding season. Therefore, adult mortality is probably highest during migration and in the wintering grounds (Ammon 1995b). Based on return rates to breeding grounds, a maximum estimate of mortality from departure to return at breeding areas would be 64% and 98% for adults and juveniles, respectively. However, these estimates are unlikely to be true estimates of survival because annual return rates to a breeding site are the product of four independent probabilities: (1) true survival, (2) site-fidelity, (3) annual variation in local site use or breeding propensity, and (4) detection rates (Sandercock and Jaramillo 2002).

Breeding

First breeding probably occurs at one year of age in both males and females (Ammon 1995b). However, data from several studies suggest a widespread male bias in populations. In a central Colorado population, the sex ratio was 61% males and 39% females (data from CBO in Ammon 1995b). Miller and McCabe (1935) collected 262 birds throughout the species' breeding range; >73% were male and >23% female. Therefore, considering the large proportion of presumably non-breeding males in the breeding sites, young males may not always breed their first year (Ammon 1995b). Lincoln's sparrows lay from three to six eggs with four or five the norm (Speirs and Speirs 1968). During a four-year study in Colorado, nest failure rates varied from 22% to 51% and the number of young fledged per egg laid varied from 34% to 62% between years (Ammon 1995b). Nest success can be significantly influenced by fluctuation in predator abundance, extreme weather events, and disturbances at the nest (Ammon 1995b).

Density

Territory sizes vary substantially among locations, from an estimated diameter of 32 m in high density populations of the Colorado Front Range (about 6 to 9 pairs/ha) to more than 100 m (0.5 to 0.7 pairs/

ha) in lower density populations in Ontario (Ammon 1995b). Even at a much finer scale, density can vary substantially. In central Colorado, the pair density at one site was three times higher (0.5 to 1.4 pairs/ha) than another site 5 km away (Wortman-Wunder 1997).

Seasonal variation in the size of territories, as well as factors determining the size and quality of a territory, are undocumented (Ammon 1995b). However, differences have been noted at a study site in the Colorado Front Range with densities of 6 to 9 pairs/ha and the central Colorado site with densities between 0.5 to 1.4 pairs/ha. Territories at the Colorado Front Range site were (1) at higher elevations (3,100 m vs. 2,600 m), (2) grazed less intensively and therefore probably had a denser understory with higher nest availability, and (3) more evenly distributed over extensive riparian-willow wetlands, while territories at the central Colorado site were strung out along a creek, resulting in a high number of peripheral territories. Additionally, counts of Lincoln's sparrows in California and Oregon were not correlated with meadow size, but distribution and abundance were associated with scores for wetness and/or extent of grazing damage (Cicero 1997).

Wortman-Wunder (1997) classified 14 territories as peripheral and 15 as central. Peripheral territories were significantly larger than central territories, but territory size was not related to vegetation composition. Overlap occurred between nearly half of these territories, while only four territories (14%) were buffered on all sides. From the available information, it is not possible to assess if territoriality limited this population. Information that would help us better understand the role of territoriality in population regulation includes survival rates, clutch size, and fledgling rates of peripheral territories compared to central territories. Data on the percentage of adult females that do not occupy a territory and therefore do not reproduce could also help assess if territoriality limits Lincoln's sparrows.

Dispersal

Information on the dispersal of Lincoln's sparrow is scarce. In Colorado, only 2% of young returned to the natal site (n = 137; data from CBO in Ammon 1995b). For adults, the return rates to breeding grounds from year to year was 37% for males (n = 123) and 36% for females (n = 85; data from CBO in Ammon 1995b). No other mark-and-recapture studies on adults or juveniles on breeding sites were found. However, Marshall (1988) reported that Lincoln's sparrows established populations in Tulare County, California between the 1930's and 1986 in newly created riparian habitat. The closest known populations of the 1930's to the newly established populations in 1986 were approximately 2.5 km away.

No information is available concerning metapopulations or source and sink populations of Lincoln's sparrows. In general though, we consider Lincoln's sparrow populations to be stable in Region 2. The life cycle diagram we constructed suggests that first year survival is the most significant factor that affects population viability (**Appendix A**).

Community ecology

In this section, we discuss interactions between the Lincoln's sparrow, their predators, competitors, and the relationship of these interactions to habitat use (**Figure 6**). Additionally, parasites and disease, and symbiotic and mutualistic interactions are discussed.

Predatory animals that coexist with Lincoln's sparrows include red squirrels (*Tamiasciurus hudsonicus*), chipmunks (*Eutamias* spp.), weasels (*Mustela* spp.), domestic cats (*Felis domestica*), shrews (*Sorex* spp.), sharp-shinned hawks (*Accipiter striatus*), Cooper's hawks (*Accipiter cooperii*), shrikes (*Lanius* spp.), gray jays (*Perisoreus canadensis*), crows (*Corvus brachyrhynchos*), and ravens (*Corvus corax*).

The most important nest predators of breeding Lincoln's sparrows at subalpine sites in Region 2 appears to be short-tailed weasels (*Mustela erminea*) and rodents (Ammon 1995b). Forty-eight percent of failed nests (n = 64) had signs of rodent predation, such as eggshells and undisturbed nest lining (Ammon 1995b). Predation rates covaried with weasel and vole (*Microtus montanus* and *Clethrionomys gapperi*) abundances, suggesting a multiple trophic interaction between weasels, voles, and birds (Ammon 1995b). At a site in Colorado, poorly concealed nests near large willow stands had a higher probability of predation than well-concealed nests far from large willow stands (Ammon 1995b). Distance to forest edge or to perch trees had no effect on predation rates.

Information on competition of the Lincoln's sparrow is scarce. Species known to occupy the same shrublands as Lincoln's sparrows include song sparrows, yellow warblers (*Dendroica petechia*), dusky flycatchers (*Empidonax oberholseri*), fox sparrows (*Passerella iliaca*), white-crowned sparrows (*Zonotrichia leucophrys*) and Wilson's warblers (Kingery 1998). Of all these species, Wilson's warblers probably live in closest association with

Figure 6. Envirogram representing the web of linkages between Lincoln's sparrow and the ecosystem in which they occur.

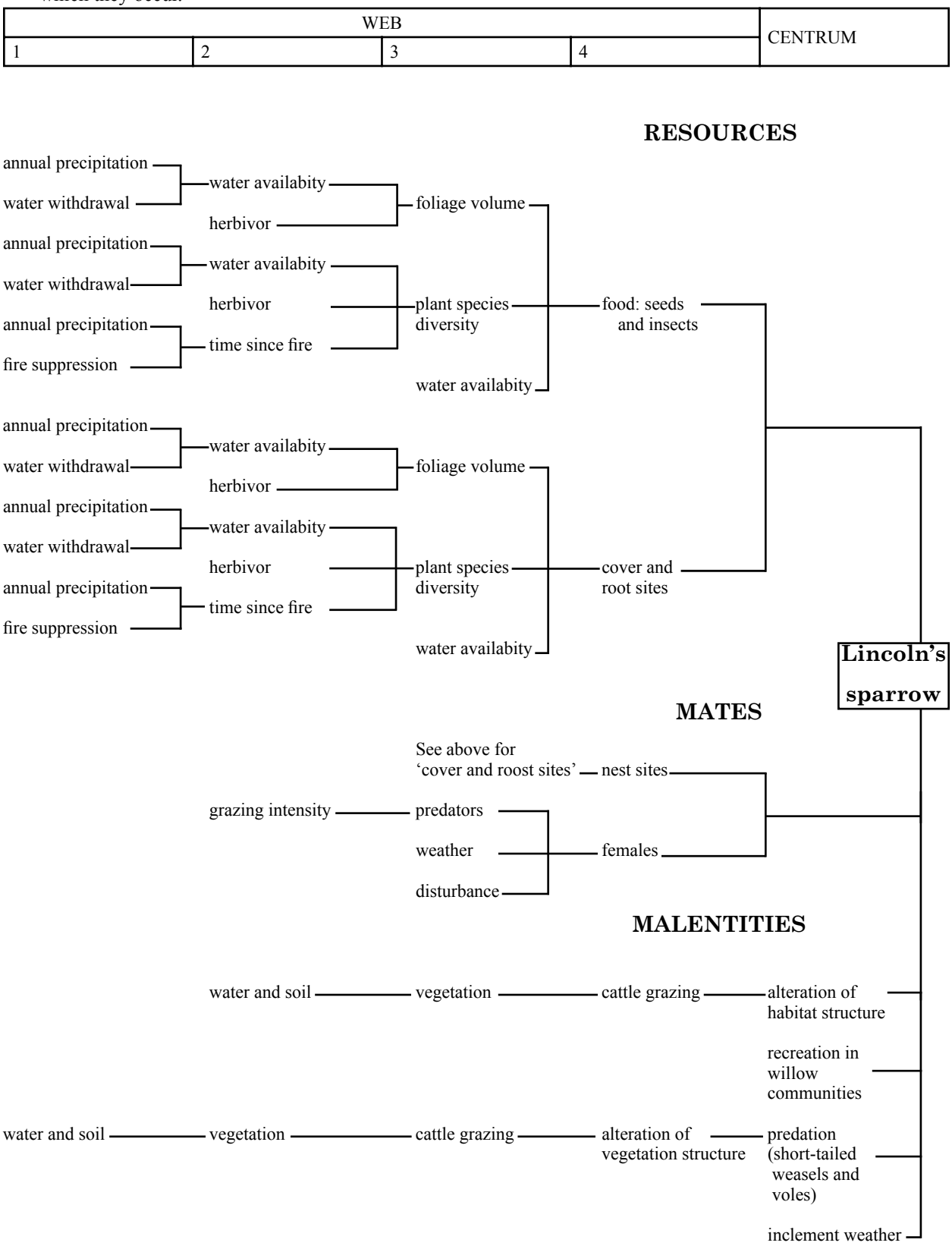
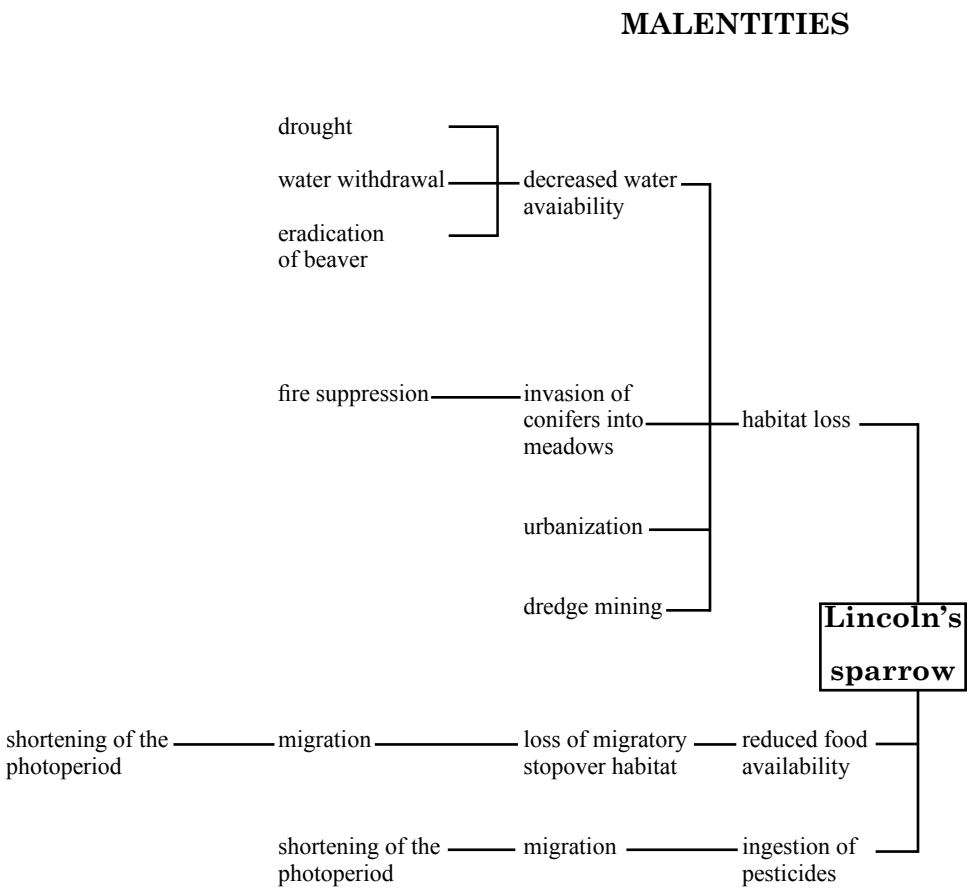


Figure 6 concluded.

WEB				CENTRUM
1	2	3	4	



Lincoln's sparrows (Kingery 1998). Brown-headed cowbirds (*Molothrus ater*) are known to parasitize the nests of Lincoln's sparrows (Speirs and Speirs 1968). However, cowbird nestlings fair dismally. No records were found of cowbirds fledging successfully from Lincoln's sparrow nests (Kingery 1998). During winter, Lincoln's sparrows are uncommonly observed at backyard bird feeders. In one case, a Lincoln's sparrow chased dark-eyed juncos (*Junco hyemalis*), a tree swallow (*Tachycineta bilolor*), and a red-backed vole (*Clethrionomys gapperi*) that got too close to the sparrow's position at a feeder (Rudy 1996). Hawkins (1986) observed a Lincoln's sparrow and a white-throated sparrow (*Zonotrichia alicollis*) sparring over a piece of corn at a feeder with the Lincoln's sparrow winning. They have also been reported feeding with dark-eyed juncos, house sparrows (*Passer domesticus*), and a Harris's sparrow (*Zonothricia querula*) in a hay pile without any aggressive interaction (Egeland 1982). Song sparrows are known to outcompete Lincoln's sparrows for perch sites (Speirs and Speirs 1968, Cicero 1997). Hendricks and Pidgeon (1990) reported that a population of Lincoln's sparrows from a 1964 study in the Beartooth Mountains of Wyoming had become extinct, while a population of Savannah sparrows (*Passerculus sandwichensis*) became established at the site. It is unknown whether or not the colonization by the Savannah sparrows is causally correlated to the extinction of the Lincoln's sparrows from the same habitat.

A peak in the defense rate of passerines typically occurs during the early-season (Stefanski 1967, Best 1977). However, Wortman-Wunder (1997) reported that intraspecific competition between adjacent nesting pairs of Lincoln's sparrows occurs at a low level throughout the nesting season. Although occasional squabbles occurred in areas of overlapping territories, the areas of overlap were mostly used for foraging with few challenges (Wortman-Wunder 1997). Wortman-

Wunder (1997) suggested that competition for space was low in her study site due to the absence of a higher defense rate during the early season. Speirs and Speirs (1968) reported that "after many hours of observations in Ontario, no threats of fighting between rival males were documented and that song was the only important territorial manifestation."

Information on the parasites and disease of Lincoln's sparrows is also scarce. The Lincoln's sparrow is a host of blood parasites *Leucocytozoon fringillinarium*, *L. majoris*, *Haemoproteus* spp., and *Plasmodium* spp. (Coatney and West 1939, cited in Bennet et al. 1975, Bennett and Cameron 1975, cited in Ammon 1995b). The nematode, *Diplotriaena bargusinica*, has been found in the air sac of one bird (Anderson 1959, cited in Speirs and Speirs 1968). The fluke, *Tamerlania melospizae*, was found in the ureter of one bird (Penner 1939, cited in Speirs and Speirs 1968). Adults are known to host louse flies (Hippoboscidae) as well as the tick *Haemaphysalis leporis-palustris* (Ammon 1995a). The effects of parasites on survival are unknown (Ammon 1995a).

No information was found on mutualistic and symbiotic interactions.

CONSERVATION

Threats

As mentioned earlier, the status of the Lincoln's sparrow is 'demonstrably secure' in Colorado and Wyoming. Therefore, the threats discussed below are likely to only affect the Lincoln's sparrow at a fine scale. 'Fine scale' is to be interpreted broadly to mean site-specific or possibly Forest-wide depending on the type and level of disturbance. Assuming similar levels of these impacts occur into the near future, it is unlikely that any of the threats discussed below will negatively affect population viability across Region 2. However, the difficulty in understanding the significance of each threat to population viability illustrates the cumulative effects problem in natural resource management and land use planning; while each single land use change results in a negligible impact, the accumulation of these individual changes over time and within a landscape or region may constitute a major impact (Theobald et al. 1997). Therefore, we do not attempt to assess the vulnerability of Lincoln's sparrows to these threats at a region-wide scale due to variable conditions of the landscape throughout the region, differences in the types and levels of disturbance from site to site, and a lack of information on how disturbance levels vary from site to site.

Livestock grazing

At the present, the most widespread cause of Lincoln's sparrow habitat deterioration in Region 2 is likely to be overgrazing by livestock. Overgrazing alters the vegetation and decreases the quality of nesting and foraging habitat. Terrestrial species, particularly birds, are responsive to changes in the vertical diversity of vegetation structure (MacArthur 1964).

Overgrazing by cattle alters habitat by decreasing the volume of the vegetation (Knopf and Cannon 1982, Schulz and Leininger 1991, Ammon and Stacey 1997). In a comparison of grazed versus ungrazed sites in Colorado, Schulz and Leininger (1990) reported that total vascular vegetation was nearly 21% greater, total shrub cover was 82% greater, and total graminoid cover was 24% greater at ungrazed sites. Additionally, canopy cover of willows was 88% greater at ungrazed sites, even though willow density was not significantly different (Schulz and Leininger 1990). Willows at ungrazed sites (8.1 years) were older than at ungrazed sites (4.8 years), indicating that vigor is higher at ungrazed sites. Overgrazing by cattle also decreases the quantities of live and dead stems of bushes (Knopf and Cannon 1982). Cattle tend to rub on dead branches when seeking shade, thereby causing them to break off (Knopf et al. 1988). Heavy grazing also decreases ground litter (Knopf and Cannon 1982, Knopf et al. 1988, Schulz and Leininger 1990). Schulz and Leininger (1990) reported that ground litter was 46% greater at ungrazed sites. Loss of ground litter contributes to higher rates of evaporation and less water available for the vegetation (Kauffman and Krueger 1984).

Alteration of natural hydrologic regimes is another undesirable consequence of heavy grazing in riparian areas. When vegetation along a stream is trampled, its stabilizing capacity is lost, bank erosion occurs, streambeds becomes wider, and stream depth becomes shallower (Knight 1994). The result of widening and shallower streambeds is a loss of habitat for Lincoln's sparrows. Heavy grazing also causes soil compaction, which increases runoff, lowers the groundwater table, decreases water availability to plants, and the site becomes drier (Kauffman and Krueger 1984, Cicero 1997).

In a comparison of wildlife communities in grazed and ungrazed montane riparian sites in Colorado, Lincoln's sparrows were three times more abundant

(grazed sites: $n = 4$; ungrazed sites: $n = 13$) in ungrazed sites (Schulz and Leininger 1991). It was suggested that the trend towards population decline at grazed sites was due to differences in vegetation between sites. (Schulz and Leininger 1990). The impacts of livestock grazing to Lincoln's sparrows were also studied in northern California and Oregon, areas with habitat similar to that in Region 2 (Cicero 1997). Lincoln's sparrows were absent from all meadows with heavy grazing damage and were most common in moderately wet to flooded meadows with low levels of grazing damage. Grazing damage was qualitatively measured along a scale from 1 to 5, based on the amount of bare ground exposed, the extent of gullying and/or streambank erosion, the presence of old or recent livestock droppings, and the network of livestock trails.

Predation and interspecific competition effects on Lincoln's sparrows may become intensified in areas where overgrazing by livestock occurs. As vegetation cover decreases, Lincoln's sparrows are increasingly vulnerable to predation. Predation rates were higher ($P < 0.05$) at nests on the ungrazed side of a fence compared to nests on the grazed side (Ammon and Stacey 1997). The consequent habitat changes of overgrazing can also alter the distribution and abundance of more tolerant species. For example, song sparrows may compete with Lincoln's sparrows for resources at lower elevations where their ranges overlap (Cicero 1997). In such areas, researchers have reported cases of interspecific competition with song sparrows being dominant (Speirs and Speirs 1968, Cicero 1997).

The vegetation structure of Lincoln's sparrow habitat is more resilient to livestock grazing during the fall or winter than the summer (Sedgwick and Knopf 1987). This is due in part to drier soils and the dormancy of vegetation (Knopf et al. 1988). Knopf et al. (1988) characterized willow communities in pastures historically grazed in the winter as healthy stands with vigorous vegetative production and regeneration. Historically summer-grazed pastures were comparatively decadent (Knopf and Cannon 1982).

Grazing by wildlife, especially moose, is likely to have a much different influence on the vegetation. Moose are thought to have important localized effects on ecosystems (Pastor et al. 1993), partly because they consume large quantities of woody shrubs and young trees. In Alaska, willow branches grazed heaviest by moose had the most growth (Wolff 1978). Heavy browsing was also associated with a greater number of stems per willow due to multiple branchings at the root crown (Wolff 1978). Based on habitat descriptions of Lincoln's sparrows, we assume that increased growth and greater numbers of stems per willow does not negatively affect them. A study in western Wyoming reported that high-grazing intensities of moose detrimentally affect some neotropical migrants during the breeding season (Berger et al. 2001). Higher levels of moose grazing were associated with shorter willows and willows with a lower percentage of volume (Berger et al. 2001). At the ground level, where heavy winter snowfall reduces willow availability, and in the vegetation canopy above which moose regularly feed, differences in the proportion of browsed willow stems were not detectable (Berger et al. 2001). However, at intermediate vegetation layers, moose densities had dramatic effects on the proportion of browsed willows (Berger et al. 2001). These alterations to the vegetation did not appear to affect Lincoln's sparrows though. Densities of Lincoln's sparrows were similar ($P = 0.5038$) at sites with high (5.2 individuals/km^2) and low (1.1 individuals/km^2) densities of moose (Berger et al. 2001). The differences between the effects of livestock grazing and moose grazing are due to factors such as higher densities of livestock that typically occur, the herding instinct in cattle, and that livestock are usually prevented from leaving an area by fences.

Recreation

Recreation is a threat to Lincoln's sparrows because this sparrow is negatively affected by human disturbance at nest sites (Ammon 1995b) and because recreation is increasing in Region 2 (USDA Forest Service 2002). In the Colorado Front Range, significantly higher nest desertion rates (17.5% nests, $n = 40$, in visited sites, vs. 4% nests, $n = 48$, in unvisited sites; $P = 0.0398$) occurred in three sites used by recreational visitors (picnicking, fishing, and hiking) compared to three sites not used for recreation (Ammon 1995b). The negative impacts of recreation are probably most detrimental in subalpine nesting habitats, as these are the areas where the highest densities of nesting Lincoln's sparrows have been reported (Ammon 1995a). Other studies have also documented the negative effects of recreation (Miller et al. 1998, Ingelfinger 2001). Miller et al. (1998) investigated the influence of recreational trails on breeding bird communities in forest and mixed-grass prairie ecosystems. Bird species composition was altered adjacent to trails in both ecosystems. Generalist species were more abundant near trails, whereas specialist species were less common. Within the grassland ecosystem, birds were less likely to nest near trails. Within both ecosystems, nest predation was greater near trails. Ingelfinger (2001) investigated the impacts of road development upon songbird density

and reported that the guild of sagebrush obligates was reduced by 50% within 100 m of roads.

Application of chemicals

While only limited information was found on the effects of pesticides to Lincoln's sparrows, pesticides are likely to pose a significant threat on winter ranges south of the United States and in local areas within the breeding range. Mexico and most of Central America make up a large portion of the Lincoln's sparrows winter range. Harmful pesticides such as DDT are still applied in these areas. Even though we assume it to be uncommon, foraging in cultivated fields during migration and winter (Ammon 1995b) puts Lincoln's sparrows at risk.

In some areas herbicides are applied to clearcuts to suppress broadleaf vegetation and hasten reforestation of coniferous trees (Santillo et al. 1989). Glyphosate is a commonly used herbicide that controls deciduous trees and shrubs, forbs, and grasses (Sutton 1978). This management tool appears to negatively impact Lincoln's sparrows as they were less abundant on treated sites relative to control sites ($P < 0.05$; Santillo et al. 1989). Lincoln's sparrows are omnivorous birds that require low brushy openings for foraging and nesting (Bent 1968). Herbicide treatment resulted in a reduction in invertebrates, seed and berry producing grasses, and forbs, which reduced food and nest availability (Santillo et al. 1989).

The application of chemicals could benefit Lincoln's sparrows in certain situations (Vera and Servello 1994). The U.S. pulp and paper industry produces large amounts of sludge as a by-product of wastewater treatment. In several regions of the United States, sludge is spread in commercial forests to regenerate forest stands, which provides a disposal alternative and the potential for improving soils and tree growth. Sludge spreading apparently benefits Lincoln's sparrows as sparrow abundance on treated sites increased relative to control sites ($P < 0.10$), which was likely in response to increases in foliage volume and/or cover near the ground. However, no information is available as to how the bioaccumulation of compounds present in sludge, such as 2, 3, 7, 8-tetrachlorodibenzo-p-dioxin, affects birds over the long term.

Fire and fire suppression

The effects of fire to Lincoln's sparrows depend on factors such as the extent, intensity, and timing of the fire, and temporal perspective. In Lincoln's sparrow habitats, late summer and fall fires are likely to be most intense since that is usually the driest time of year. Spring fires are likely to be less intense due to high moisture levels. A study in Arizona (Stein et al. 1992) documented that willows are sensitive to a wide range of fire intensities. Willows were subjected to fires under three fuel intensities, and each intensity resulted in charring of the entire willow base, killing the cambium and vascular tissue, and resulting in death of all above ground vegetation (Stein et al. 1992). Belowground plant material was not affected by burning at any fuel level (Stein et al. 1992). Willows resprouted vigorously within days of the fire.

In Minnesota, species that required wetland shrub ecosystems were less abundant at burned sites than unburned sites (Hanowski et al. 1999). Lincoln's sparrows are also likely to be less abundant immediately following a burn but, they should become more common as the willows regenerate. In general though, it is likely that fire at high-elevation riparian sites within Region 2 will benefit Lincoln's sparrows by creating early seral conditions.

Fire suppression has been a common management practice throughout much of Region 2 over the last 100 years. The mean fire-return interval ranges from 100 to 300 years in lodgepole pine forests and from 200 to 400 years in spruce-fir forests (Knight 1994). Lincoln's sparrows are most commonly found in wetlands adjacent to these forest types. At a broad scale, it is likely that fire suppression has had less of an influence upon landscape pattern in the above-mentioned higher elevation forests relative to lower elevation forests such as ponderosa pine (*Pinus ponderosa*) and mixed-conifer, where the mean fire-return interval is much shorter and fire suppression more effective. Over time though, it is possible that fire suppression will negatively affect Lincoln's sparrows by promoting the invasion of conifers into meadows, thereby decreasing nesting and foraging habitat.

Timber harvest

The impacts of timber harvest to Lincoln's sparrows will vary from site to site, depending on the location and structure of the forest at the time of harvest, the form and intensity of harvest, and the temporal perspective. In general, however, silvicultural prescriptions that favor maintenance and expansion of shrub-dominated openings in association with water will favor Lincoln's sparrows. Furthermore, silviculture that favors the maintenance and development of aspen near water will promote beaver and favor Lincoln's sparrows in the long run. On the other hand, any management

that ultimately reduces the extent of shrub-dominated riparian areas will be harmful.

Several studies have documented that timber harvest can be beneficial to Lincoln's sparrows (Marshall 1988, Stevenson et al. 1998, Hobson and Schieck 1999). In British Columbia, a study comparing bird abundance after two intensities of partial cutting (30% and 60% volume removal) to clearcuts and uncut natural stands found that Lincoln's sparrows were detected almost exclusively in clearcuts (Stevenson et al. 1998). Clearcuts created early seral conditions favored by the Lincoln's sparrow (Stevenson et al. 1998). No information was presented in the report indicating whether the clearcuts were at riparian sites or upland sites. We assume that if clearcutting in Region 2 occurs in riparian areas and allows willow-shrub communities to become re-established, it will benefit Lincoln's sparrows. Lincoln's sparrows also benefited from timber harvests in central California. Populations were established between the 1930's and 1986 in a newly created wet meadow that was formed through timber harvests that removed conifer thickets and thinned the canopy (Marshall 1988). Finally, in an investigation of the effects of disturbance types to bird communities in Alberta, Canada, Hobson and Schieck (1999) observed that Lincoln's sparrows had higher densities on post-harvest stands than post-fire stands. This was possibly due to the greater relative abundance of larger live residual trees and a taller and more dense shrub layer following harvest (Hobson and Schieck 1999). However, the large initial differences in abundance diminished 14 years after disturbance.

Timber harvest could negatively impact wetlands in which Lincoln's sparrows nest. Timber harvesting and the associated road building can increase erosion and sedimentation, and thus change the condition of the wetlands. Additionally, there is the threat of nest abandonment due to disturbances during timber harvests and road building.

Mining

Mining has the potential to negatively impact wildlife whether it is through the loss of habitat, disturbance, or environmental contamination. Dredge mining for gold and other precious metals has effected Lincoln's sparrows at sites throughout Region 2 through the loss of habitat. Recovery of the system at many of these sites has not occurred, even though mining stopped long ago. This emphasizes the potential for long-term impacts due to mining activities. While no studies were found that specifically document the negative effects of mining on Lincoln's sparrows, other studies have documented impacts to birds that use similar habitat (C. Custer et al. 2001, T. Custer et al. 2001). House wrens (*Troglodytes aedon*) downstream of the Whitewood Creek in South Dakota had elevated arsenic levels as a result of over 250,000 tons of arsenic associated with gold ore in the form of arsenopyrite being discharged into the creek between 1920 and 1977 (T. Custer et al. 2001). Along the Arkansas River in Colorado, tree swallows (*Tachycineta bicolor*) had elevated levels of lead as a result of gold and silver mining and the associated ore processing near Leadville, CO (C. Custer et al. 2001). Lead levels in nestling tree swallow livers and diet were highest at sites closest to the lead source with the proportion containing lead declining at sites farther downstream.

Urbanization

The large amount of federal lands in the western U.S. are an important factor attracting immigrants to the Rocky Mountain region (Rudzitis and Streatfield 1992). Counties that contain or are adjacent to federally designated wilderness areas grew two to three times faster than all other counties in the country beginning in the 1970s (Rudzitis and Johansen 1989). Within Region 2, this is particularly true in Colorado and parts of western Wyoming. For example, Colorado mountain resort counties (counties with a major ski resort) grew at an annual rate of 8.5% between 1960 and 1990, more than three times the state average (Theobald and Riebsame 1995). Lincoln's sparrows are directly affected by urbanization through the permanent loss of habitat. A major indirect impact from urbanization is the increased recreational demand. Disturbance due to recreation can cause nest desertion by Lincoln's sparrows.

In a study of the impacts of urbanization on riparian bird communities, bird species richness and density decreased at a location, as the number of bridges near that location increased and as the volume of native vegetation decreased (Rottenborn 1999). Lincoln's sparrows were not observed in this study, but Wilson's warblers, an ecologically similar species, were observed. Wilson's warblers were categorized as sensitive to urbanization, and from this we can make the inference that the response of Lincoln's sparrows would be similar.

Natural disturbances

Exposure during irregular midsummer snowstorms can cause the loss of Lincoln's sparrow

broods, but these events may be rare. One study documented only 5% loss (Ammon 1995b). Eggs are relatively tolerant of temperature fluctuations during incubation (Ammon 1995b). Adult mortality related to exposure is not quantified (Ammon 1995b). It is likely that other natural disturbances, such as wildfire have few negative consequences for Lincoln's sparrows within Region 2.

Exotic species

The biggest threat to Lincoln's sparrow with respect to exotic species is likely due to invasion by saltcedar (*Tamarix ramosissima*). It has spread throughout the southwest, up the Rio Grande and Colorado River drainages and throughout the Great Basin (Stevens and Walker 1998). Saltcedar, which is a facultative phreatophyte, vigorously consumes water and invades lowlands and riparian areas, where it competitively replaces native grasses, forbs, shrubs, and trees (Stevens and Walker 1998). As saltcedar communities establish, native species are reduced in number and replaced (Stevens and Walker 1998). The resulting vegetative communities are much less valuable to wildlife than are the original native communities (Stevens and Walker 1998). Songbird species density and total number of birds decrease as saltcedar invades and increases in density (Stevens and Walker 1998). Although saltcedar does not currently pose a significant problem within Region 2, it could pose a problem for migrating Lincoln's sparrows. Yong et al. (1998) reported that Wilson's warblers, an ecologically similar species to Lincoln's sparrows, appear to prefer native willow habitat along the middle Rio Grange during spring migration as they were able to deposit fat stores and resume migration in a short period of time. The mechanism for this may be the decreased vegetation species diversity, which would reduce arthropod and seed diversity and abundance. Thus, it was suggested that habitat alteration might negatively influence populations of Wilson's warblers during the stopover period. Another bird that has declined as the result of conversion of willow and other native habitats into less-suitable habitats, including saltcedar, is the endangered southwestern willow flycatcher (*Empidonax traillii extimus*) (U.S. Fish and Wildlife Service 1995).

Direct human impacts

Over-utilization for commercial, recreational, scientific, or educational purposes does not threaten the continued persistence of Lincoln's sparrows in Region 2.

Reduced water availability

Another threat to Lincoln's sparrows at a broad scale might be decreased water availability. Colorado's population grew from 3.3 to 4.3 million from 1990 to 2000 (http://www.cdphe.state.co.us/el/documents/ECADS/App%20B4.0%20Water%20Quantity.pdf), resulting in higher demands for water withdrawal. In 1995, total water withdrawal from Colorado was 13,800 million gallons per day (http://www.cdphe.state.co.us/el/documents/ECADS/App%20B4.0%20Water%20Quantity.pdf). When the possibility of an extended drought (http://wa.water.usgs.gov/news/news.wri024176.html) is coupled with increasing demands for water withdrawal, the end result might be the loss of riparian-willow communities as sites dry up.

Conservation Status of Lincoln's Sparrows in Region 2

It appears that anthropogenic influences have only had localized impacts on population viability of Lincoln's sparrows in Region 2. Between 1966 and 2000 (**Table 2**), no trends were detected by the BBS within Region 2 for the breeding population of this sparrow (Sauer et al. 2001). The Natural Heritage Program classifies Lincoln's sparrows as 'demonstrably secure' in Colorado and Wyoming, the only states in Region 2 where breeding commonly occurs (NatureServe 2001). No information was found whether riparian-willow communities are decreasing within Region 2, so there is no strong evidence indicating that populations of Lincoln's sparrows face risks due to habitat loss. However, at a national level, riparian shrublands increased 6.6% from 1986 to 1997 (Dahl 2000) and remained constant between the mid-1970's and mid-1980's (Dahl and Johnson 1991). If the trend of riparian shrublands in Region 2 is similar, then it is not likely that habitat loss threatens population viability.

Densities of Lincoln's sparrows vary significantly within Region 2, with the highest densities being reported in extensive riparian-willow shrublands at high (3,100 m) elevations (Ammon 1995a). Studies have linked activities such as livestock grazing and recreation to decreased nest density, lower recruitment, and higher vulnerability to predation (Schulz and Leininger 1991, Ammon 1995a, Cicero 1997). These and other significant threats to Lincoln's sparrows have been discussed in detail above under "Threats." Currently, these threats are likely to only affect Lincoln's sparrows at a fine scale. However, the viability of Lincoln's sparrows could be impaired throughout Region 2 if broad management changes are made.

Reed (1995) categorized Lincoln's sparrows as 'most vulnerable' to extirpation due to several life history characteristics. The criteria were that Lincoln's sparrows: (1) occupy a narrow geographic range, (2) occur at low densities inside their range, (3) are habitat specialists, (4) have high susceptibility to brown-headed cowbird parasitism, and (5) are migrants and thus, are dependent upon on habitats in more than one geographic range. However, Reed presented no data to substantiate his claim. Additionally, another study (Speirs and Speirs 1968) documented that the impacts of brown-headed cowbird parasitism to Lincoln's sparrows are negligible, and only one report (Hendricks and Pidgeon 1990) was found on the extirpation of Lincoln's sparrows from a specific site. Still, this sparrow is a habitat specialist of riparian-willow communities, and it is known to be vulnerable to actions that degrade these sites. Therefore, the RGNF is proposing to list this sparrow as a MIS. As a MIS, it will serve as a barometer of the effects of forest management activities on wildlife species associated with riparian-willow communities.

Management of Lincoln's Sparrows in Region 2

Implications and potential conservation elements

As mentioned above under "Threats", overgrazing by livestock and recreation are two of the primary threats that can decrease the abundance of Lincoln's sparrows. Overgrazing by livestock and recreation lower bird abundance by decreasing the structural diversity in wetland habitats, disturbing birds during the nesting phase, and increasing vulnerability to predation. Fire suppression can also affect the distribution and abundance of Lincoln's sparrows by allowing conifers to invade adjacent wetlands. Another potential conservation element necessary for Lincoln's sparrows is conservation of riparian habitat along migration pathways. Alteration and loss of riparian habitats have potential to negatively affect migratory species that breed and winter elsewhere, by reducing the amount of suitable habitat they can visit to find food and replenish fat stores.

Livestock grazing

Cattle and sheep grazing is a common use of national forests in Region 2, with cattle as the primary grazing animal. Overgrazing in Lincoln's sparrow habitat can lead to lower volumes of vegetation (Knopf and Cannon 1982, Schulz and Leininger 1991, Ammon and Stacey 1997), reduced vigor of willows, decreased quantities of live and dead stems of bushes (Knopf and Cannon 1982), and decreased ground litter (Knopf and Cannon 1982, Knopf et al. 1988, Schulz and Leininger 1990). Additionally, heavy grazing can alter natural hydrologic regimes important to maintaining ideal nesting habitat and increase the vulnerability of Lincoln's sparrows to predation and interspecific competition (Ammon and Stacey 1997, Cicero 1997).

In areas where overgrazing by livestock has degraded riparian-willow vegetation, some rest from grazing may be needed to re-establish healthy stands of shrubs (Schulz and Leininger 1990). Skovlin (1984, cited in Schulz and Leininger 1990) recommended a 5-year rest followed by proper livestock management. Considerable recovery can take place after only five years of livestock exclusion from riparian zones (Rickard and Cushing 1982).

Under proper management, the impacts of livestock grazing to Lincoln's sparrows can be minimized. Conservation elements that address the threats created by livestock grazing are numerous. The Wyoming Bird Conservation Plan (Cerovski et al. 2001) recommends that the best management practices for grazing focus on protecting riparian areas during crucial growing periods. Several key recommendations were:

1. Grazing management plans should be developed and evaluated on a case-by-case basis, because no single grazing strategy will fit all situations.

2. Proper stocking rates and livestock distribution should be maintained to protect riparian ecosystems.

3. The length of the grazing period within a riparian zone should be based on the areas livestock are actually using, not the entire pasture.

4. Livestock should be excluded from riparian areas with high risk and poor recovery potential when there is no practical way to protect those areas while grazing adjacent uplands.

5. Fencing may be the best alternative for rapid restoration of riparian ecosystems. Fences that parallel a stream should be located well outside the riparian zone so that animals trailing along the fence will not be impacting the streambanks and riparian vegetation.

6. If riparian areas are fenced to exclude livestock, access to a short, straight, stable section of stream with a gentle bank should be provided as a livestock watering site.

7. Spring grazing may increase the herbaceous component of the understory, which is very important for ground foraging and seed eating birds, and reduce browsing pressure on woody species, which are essential for maintaining riparian functions. Spring grazing should occur before nesting; otherwise, it could result in trampling of nests.

8. Hot season grazing (mid- to late summer) in riparian areas should be avoided. During this period, livestock are especially likely to concentrate in riparian areas and can seriously degrade the vegetation and stream channel.

9. Light fall grazing can help maintain functioning riparian areas if at least 60 to 70% of plant growth remains (use is no more than 30 to 40%), no significant consumption of willows and other shrubs occurs, and stubble heights of 10 to 15 cm are retained.

10. Livestock distribution and forage should be improvedby using salt and mineral blocks, but avoid placing them within riparian areas (keep them at least 0.8 km from the stream) or in immediately adjacent uplands.

11. Shade and water in upland areas should be developed to help spread grazing pressure.

In riparian areas where severe damage by livestock grazing has already occurred, long-term exclusion of livestock on meadows, combined with erosion-control measures, will especially benefit Lincoln's sparrows and other similar species because of the combined vegetative and hydrologic effects (Cicero 1997). Additionally, the reintroduction of beavers can facilitate wetland recovery time in severely damaged wetlands where gullying has occurred and willow re-establishment is a goal (Cerovski et al. 2001, McKinstry et al. 2001). When reintroducing beaver, stream gradients should be less than 4%, and there should be an adequate supply of woody vegetation for food and dam-building materials (Cerovski et al. 2001).

Recreation

Recreation is another common use of USFS lands in Region 2 that threatens Lincoln's sparrows. Recreation takes place in many forms but camping, picnicking, hiking, fishing, and snowmobiling are likely to be the activities that are most detrimental to Lincoln's sparrows. Cerovski et al. (2001) suggested several conservation elements to reduce the impacts of recreation. Several key recommendations were:

1. Consider potential disturbances to birds and habitat when planning or locating camping sites, picnic areas, and other sites of human activity within riparian areas.

2. Locate new recreation sites outside of riparian areas wherever possible. If sites must be within riparian zones, concentrate them in one area, rather than spreading them throughout the riparian area.

3. Avoid constructing new trails along or parallel to riparian areas.

4. Provide firewood at developed campgrounds to decrease the use of riparian areas as a wood source.

5. Promote 'Tread Lightly' recreation ethics.

6. Manage or restrict all-terrain vehicles, bicycles, and horses in riparian areas and wet meadows because soil compaction and ruts caused by these uses can lead to the drying of these areas.

7. Plant dense native vegetation, such as willows, to screen and reduce human use of fragile or vulnerable riparian areas.

8. Prohibit the use of foggers for mosquito control in riparian habitats, especially during the nesting season, so a food source remains available for birds.

Timber harvest

Another management tool that can be applied to benefit Lincoln's sparrows in riparian areas is timber harvest. Timber harvest, especially clearcutting, creates the early seral conditions that are desirable to Lincoln's

sparrows (Stevenson et al. 1998, Hobson and Schieck 1999). In a study that compared bird abundance after two intensities of partial cutting (30% and 60% volume removal) to clearcuts and uncut natural stands, Lincoln's sparrows were detected almost exclusively in clearcuts (Stevenson et al. 1998). Hobson and Schieck (1999) reported that areas where timber harvest occurred received more use by Lincoln's sparrows than areas where fire occurred, which is likely due to the shrub component that remained post-harvest. However, the large initial differences in abundance diminished by 14 years after disturbance. Fire also creates early seral conditions and should be beneficial to Lincoln's sparrows.

Tools and practices

Standard point count or transect methods represent efficient methods to monitor presence and abundance of Lincoln's sparrows based on the singing of breeding males (Ammon 1995b). Males sing vigorously from elevated perches during the breeding season, particularly near watercourses or along meadow edges, and thus are easily detectable (Cicero 1997). Only males are known to sing (Ammon 1995b). Singing begins at, or shortly before arrival on the breeding grounds (around mid-May in Region 2) and practically ceases during mid to late incubation (late June to mid-July in Region 2) except for a few songs early in the morning, then increases again greatly when the young are about to leave the nest or if nests fail early (Speirs and Speirs 1968, Ammon 1995a). Cicero (1997) completed surveys of all singing males during one or, at most two consecutive mornings (2 to 5 hours/morning) due to the size and discrete, linear configuration of most meadows within her site.

Broadcast conspecific calls have been used to detect Lincoln's sparrows with variable success. Wortman-Wunder (1997) used broadcast conspecific songs during the breeding season to locate Lincoln's sparrows and reported that response varied widely, from no response at all to a vigorous response from both adults. She was not able to discern a pattern of response related to particular males, certain times of day or breeding stage.

While the above mentioned techniques work well for site specific studies, broad scale information is needed by managers when developing management plans and conservation actions. Population monitoring is the backbone of avian conservation (Leukering et al. 2000). Tools that are used to estimate population trends include the BBS, MAPS, and Monitoring Colorado's Birds programs.

While the methods of the BBS and MAPS have been discussed in the 'Existing regulatory mechanisms, management plans, and conservation strategies' section, presented here are the weaknesses of these two programs. Currently, the BBS is likely to be the most useful tool as an indicator of population change at a continental or regional scale. However, the BBS has significant flaws associated with trying to use it to guide local or regional management decisions. First, the design and implementation of the BBS is such that results generated from these efforts are often inconclusive due to the difficulty associated with interpreting index counts (Sauer 2000). In addition, many species and habitats are inadequately sampled by the BBS, and BBS data do not reliably predict population trends at fine geographic scales (Sauer 2000). BBS data also only have limited use for determining responses of bird communities to environmental change and/or management action, in part because habitat data are not recorded during BBS counts (Leukering et al. 2000). The MAPS program has only been collecting information on avian productivity, survivorship, and distribution for several years, and the demographic information is not yet available. Information about BBS and MAPS programs can be obtained from the following web sites: http://www.mbr-pwrc.usgs.gov/bbs/bbs.html (BBS) and http://www.birdpop.org/maps.htm (MAPS).

The Monitoring Colorado's Birds project focuses on obtaining count-based data for all breeding-birds species in the state on a randomly-allocated and habitat-stratified basis. Leukering et al. (2000) summarized the methods and future objectives for this project. Three methods are used (transects, colony counts, and censussing) to obtain population data for Colorado's breeding-bird species, with transects being the primary method. Transects (15 point counts/ transect) are performed in 30 randomly-selected stands in each of the 14 habitats monitored. Standard distance-sampling techniques are used during all transect surveys, and density estimates of bird species are derived using program DISTANCE (Thomas et al. 1998). The goal of Monitoring Colorado's Birds is to expand the program to the level of Bird Conservation Region (BCR) instead of a state boundary. BCRs are more ecologically-meaningful management units for birds because they encompass distinct ecoregions in North American that host similar bird communities. Colorado is primarily comprised of two distinctly contrasting BCRs: the Shortgrass Prairie (BCR#18) and the Southern Rockies/

Colorado Plateau (BCR#16), each of which extend into neighboring states. A BCR-level plan would require that all states occupying significant positions of BCRs contribute proportionately to fund monitoring efforts in those BCRs. Such a plan would be more cost-effective because it would eliminate duplicate efforts by states to obtain independent data sets from habitats they share with other states, while still providing meaningful data on bird populations that could be used at the state level. More information on Monitoring Colorado's Birds is available at http://www.rmbo.org/homeflash.html.

At the statewide scale, the best method available for delineating potential Lincoln's sparrow habitat is GAP data. Problems associated with GAP include the coarse resolution and amount of error associated with its estimates. At a forest-wide scale, GAP data are likely a more reliable tool as it is easier to ground truth the estimates due to the smaller scale. Information on Wyoming GAP data is available at www.sdvc.uwyo.edu/wbn/gap.html, and for Colorado GAP data go to http://ndis.nrel.colostate.edu/cogap/stvdwnld/cgstvddc.html. Once potential habitat is delineated, managers will want to identify which sites are most likely occupied. The difficulty therein is that only limited information is available that quantifies the structural characteristics selected by Lincoln's sparrows.

Information Needs

Much of the Lincoln's sparrows biology and ecology remains unknown (Ammon 1995a). Currently, our best understanding of Lincoln's sparrow habitat during the breeding season identifies it as riparian-shrub (especially willow) communities at higher elevations (typically above 2,000 m in Wyoming and Colorado). More information is needed on the physical characteristics of the vegetation and waterflow at occupied sites. Such information would enable managers to assess which characteristics are important to the species and which riparian-willow habitats are most likely to be occupied by Lincoln's sparrows. With such information, impacts of other forest uses could be better mitigated.

For management purposes, more information is needed on the Lincoln's sparrow's response to fine and broad scale changes in habitat, especially related to livestock grazing and concentrated recreational use. For example, (1) at what threshold does livestock grazing negatively impact nesting Lincoln's sparrows, and (2) at what level does grazing occur in habitats identified as Lincoln's sparrow habitat within each forest in Region 2? Similar answers about recreational impacts would also benefit managers.

More information is needed on the migration ecology of Lincoln's sparrows. Knowledge of their habitat use during migration and how habitat loss along migratory pathways affects survival is limited. Additionally, mortality for many birds is highest during migration, and only limited information is known about migration-related mortality of the Lincoln's sparrow. However, the USFS is limited in its ability to manage the Lincoln's sparrow at migration stop-over habitat since most of these areas are not managed by the USFS. Finally, more information on the dispersal of adults and juveniles would provide a better understanding of population demographics.

DEFINITIONS

Central territory is when an entire territory is bounded by other Lincoln's sparrows territories (Wortman-Wunder 1997).

Management Indicator Species are certain species selected for use in land management planning because their population changes are believed to indicate the effects of management activities (36 CFR 219.19) (http://www.fs.fed.us/r2/riogrande/planning/planreversal.html).

Peripheral territory is when the entire territory is not bounded by other Lincoln's sparrows territories (Wortman-Wunder 1997).

Territory is any area defended against the intrusion of others (Ricklefs 1993).

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APPENDIX A

Matrix Model Assessment of Lincoln's Sparrows

Life cycle model

Due to similarities of life history characteristics and a dearth of demography data, we pooled the data available for Lincoln's sparrows (*Melospiza lincolnii*), fox sparrows (*Passerella iliaca*), and Wilson's warblers (*Wilsonia pusilla*) together to construct a life cycle model. The studies of Speirs and Speirs (1968), Ammon (1995), Ammon (1999), and Weckstein et al. (2003) provided the basis for formulating a life cycle graph for Lincoln's sparrow that comprised two stages (censused at the egg stage and "adults"), and assigned a lower clutch size to yearlings. Survival rates for "adults" came from Ammon (1995) and Ammon (1999). Because no estimate for first-year survival was available, and even the data for "adult" survival were sparse, first-year and "adult" survival (P_{21}) were assigned values that yielded a population growth rate (λ) of 1.0. This "missing element" method (McDonald and Caswell 1993) is justified by the fact that, over the long term, λ must be near 1 or the population will go extinct or grow unreasonably large. We bracketed what we felt were reasonable ranges of values by having a high adult to first year-survival ratio case (P_{22} = 0.59, P_{21} = 0.18) and a low adult to first-year survival case (P_{22} = 0.5, P_{21} = 0.225). From the resulting life cycle graph (**Figure A1**), we produced a matrix population analysis with a post-breeding census (McDonald and Caswell 1993, Caswell 2000). The model has two kinds of input terms: P_i describing survival rates, and m_i describing fertilities (**Table A1**). **Figure A2a** shows the symbolic terms in the projection matrices corresponding to the life cycle graphs. **Figure A2b** gives the corresponding numeric values for the low-ratio as well as the high-ratio case. The model assumes female demographic dominance so that, for example, fertilities are given as female offspring per female; thus, the egg number used was half the total clutch, assuming a 1:1 sex ratio. λ, the population growth rate, was 1.003 for the high ratio case and 1.006 for the low ratio case, based on the estimated vital rates used for the matrix. Although these suggest stationary populations, the λ value (~1.0) was used as an assumption for deriving a vital rate, and should not be interpreted as an indication of the general well being of the population. Other parts of the analysis provide a better guide for assessment.

Sensitivity analysis

A useful indication of the state of the population comes from the sensitivity and elasticity analyses. *Sensitivity* is the effect on population growth rate (λ) of an absolute change in the vital rates (a_{ij}, the arcs in the life cycle graph [**Figure A1**] and the cells in the matrix, **A** [**Figure A2**]). Sensitivity analysis provides several kinds of useful information (see Caswell 1989, p.118-119). First, sensitivities show "how important" a given vital rate is to population growth rate (λ) or fitness. For example, one can use sensitivities to assess the relative importance of survival (P_i) and reproductive (F_i) transitions. Second, sensitivities can be used to evaluate the effects of inaccurate estimation of vital rates from field studies. Inaccuracy will usually be due to paucity

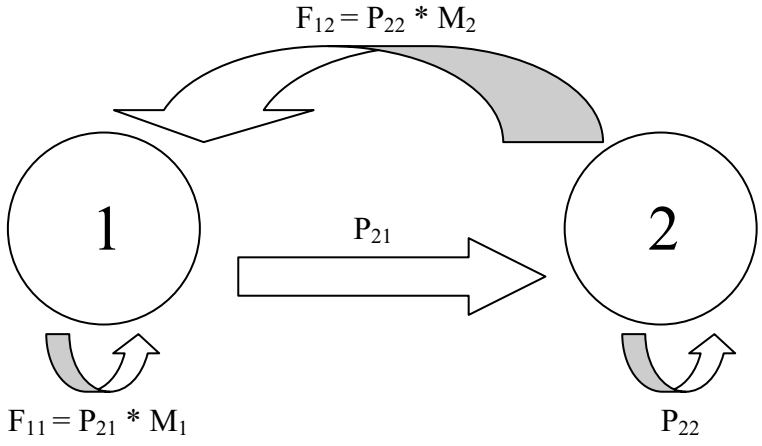

Figure A1. Life cycle graph for Lincoln's sparrow. The numbered circles (nodes) represent the two stages. The arrows (arcs) connecting the nodes represent the vital rates — transitions between age-classes such as survival (P_{ji}) or fertility (the arcs pointing back toward the first node). Note that reproduction begins in the first year.

Table A1. Parameter values for the component terms (P_i and m_i) that make up the vital rates in the projection matrices for Lincoln's sparrow. Bracketed values are for the low-ratio case.

Parameter	Numeric value	Interpretation
m_1	2	Number of female eggs produced by a first-year female
m_2	2.5	Number of female eggs produced by an "adult" female
P_{21}	0.18 [0.225]	First-year survival rate [low-ratio case]
P_{22}	0.59 [0.5]	"Adult" survival rate [low-ratio case]

	1	2
1	F_{11}	F_{12}
2	P_{21}	P_{22}

Figure A2a. Symbolic values for the projection matrix of vital rates, **A** (with cells a_{ij}) corresponding to the Lincoln's sparrow life cycle graph of Figure A1. Meanings of the component terms and their numeric values are given in Table A1.

	1	2
1	0.36	1.475
2	0.18	0.59

Figure A2b. Numeric values for the high-ratio case of the matrix whose symbolic values are given in Figure A2a. The high-ratio case assumes a relatively wide disparity between "adult" survival (P_{22} = 0.59) and first-year survival (P_{21} = 0.18).

	1	2
1	0.45	1.25
2	0.225	0.5

Figure A2c. Numeric values for the low-ratio case of the matrix whose symbolic values are given in Figure A2a. The low-ratio case assumes a smaller disparity between "adult" survival (P_{22} = 0.5) and first-year survival (P_{21} = 0.225).

of data, but could also result from use of inappropriate estimation techniques or other errors of analysis. In order to improve the accuracy of the models, researchers should concentrate additional effort on transitions with large sensitivities. Third, sensitivities can quantify the effects of environmental perturbations, wherever those can be linked to effects on stage-specific survival or fertility rates. Fourth, managers can concentrate on the most important transitions. For example, they can assess which stages or vital rates are most critical to increasing the population growth (λ) of endangered species or the "weak links" in the life cycle of a pest. **Figure A3** shows the "possible sensitivities only" matrix for this analysis (one can calculate sensitivities for non-existent transitions, but these are usually either meaningless or biologically impossible — for example, the sensitivity of λ to moving from Age-class 3 to Age-class 2).

In general, changes that affect one type of age-class or stage will also affect all similar age-classes or stages. For example, any factor that changes the annual survival rate of Age-class 3 females is very likely to cause similar changes in the survival rates of other "adult" reproductive females (those in Age-classes 4 and 5). Therefore, it is usually appropriate to assess the summed sensitivities for similar sets of transitions (vital rates). For the high-ratio case, the result is that the summed sensitivity of λ to changes in survival is of

Figure A3a. Sensitivity matrix, **S**, for the high-ratio case. The three transitions to which the λ of Lincoln's sparrow is most sensitive are highlighted: first-year survival (Cell s_{21} = 1.397, 54% of the total), second-year survival (s_{32} = 0.609), and first-year fertility (s_{11} = 0.391).

	1	2
1	0.391	0.17
2	1.397	0.609

Figure A3b. Sensitivity matrix, **S**, for the low-ratio case. The three transitions to which the λ of Lincoln's sparrow is most sensitive are highlighted: first-year survival (Cell s_{21} = 1.177, 49% of the total), second-year survival (s_{32} = 0.524), and first-year fertility (s_{11} = 0.476).

	1	2
1	0.476	0.212
2	1.177	0.524

overriding importance. Lincoln's sparrows show much greater sensitivity (78 % of total) to changes in survival, with first-year survival alone accounting for 54% of the total. The major conclusion from the sensitivity analysis is that first-year (egg to yearling) survival is very important to population viability. The low-ratio case is similar but places a slightly less emphasis on survival (71% of total).

Elasticity analysis

Elasticities are useful in resolving a problem of scale that can affect conclusions drawn from the sensitivities. Interpreting sensitivities can be somewhat misleading, because survival rates and reproductive rates are measured on different scales. For instance, a change of 0.5 in survival may be a large alteration (e.g., a change from a survival rate of 90 % to 40 %). On the other hand, a change of 0.5 in fertility may be a very small proportional alteration (e.g., a change from a clutch of 3,000 eggs to 2,999.5 eggs). Elasticities are the sensitivities of λ to *proportional* changes in the vital rates (a_{ij}) and thus partly avoid the problem of differences in units of measurement. The elasticities have the useful property of summing to 1.0. The difference between sensitivity and elasticity conclusions results from the weighting of the elasticities by the value of the original arc coefficients (the a_{ij} cells of the projection matrix). Management conclusions will depend on whether changes in vital rates are likely to be absolute (guided by sensitivities) or proportional (guided by elasticities). By using elasticities, one can further assess key life history transitions and stages as well as the relative importance of reproduction (F_i) and survival (P_i) for a given species.

Elasticities for Lincoln's sparrow are shown in **Figure A4**. For the high-ratio case, λ is most elastic to changes in "adult" survival (e_{22} = 35.8% of total elasticity on arc P_{22}, the self-loop arc from the second node back to the second node in **Figure A1**). Next most elastic are first-year survival and "adult" reproduction ($e_{12} = e_{21}$ = 25.1% of total elasticity). Least important is reproduction by first-year birds (14% of total elasticity). The sensitivities and elasticities for Lincoln's sparrow differ in emphasizing first-year survival for the sensitivities and "adult" survival for the elasticities. The summed survival elasticities account for 60.9% of the total (compared to 39.1% for the summed reproductive elasticities). Thus, survival rates are the data elements that warrant careful monitoring in order to refine the matrix demographic analysis. For the low-ratio case, the elasticities of λ to changes in first-year survival, "adult" survival and "adult" fertility are all almost equal. The summed survival (52.4%) and fertility (47.6%) elasticities are more similar than for the high-ratio case.

Other demographic parameters

The *stable age distribution* (SAD, **Table A2**) describes the proportion of each age-class in a population at demographic equilibrium. Under a deterministic model, any unchanging matrix will converge on a population structure that follows the stable age distribution, regardless of whether the population is declining, stationary or increasing. Under most conditions, populations not at equilibrium will converge to the SAD within 20 to 100 census intervals. For Lincoln's sparrow at the time of the post-breeding annual census (just after the end of the breeding season),

	1	2
1	0.140	0.251
2	0.251	0.358

Figure A4a. Elasticity matrix, **E**, for the high ratio case. The three transitions to which the λ of Lincoln's sparrow is most sensitive are highlighted: adult survival (Cell e_{22} = 0.36, or 36% of the total), and then slightly lower equivalent values (both 25%) for first-year survival (e_{21}) and adult fertility (e_{12}).

	1	2
1	0.213	0.263
2	0.263	0.26

Figure A4b. Elasticity matrix, **E**, for the low ratio case. No values are highlighted because they are nearly equivalent (all ~ 25%).

Table A2. Stable age distribution (right eigenvector) for the high- and low-ratio cases. At the census, slightly more than two-thirds of the individuals in the population should be eggs.

Stage	Description	High-ratio	Low-ratio
1	Eggs (to yearling)	0.696	0.692
2	"Adult" females	0.304	0.308

eggs represent 69.6 % of the population. *Reproductive values* (**Table A3**) can be thought of as describing the "value" of a stage as a seed for population growth relative to that of the first (newborn or, in this case, egg) stage. The reproductive value of the first stage is always 1.0. An "adult" female individual in Stage 2 is "worth" 3.57 eggs (Caswell 2001). The reproductive value is calculated as a weighted sum of the present and future reproductive output of a stage discounted by the probability of surviving (Williams, 1966). The "adult" females are important stages in the life cycle. The cohort generation time for this species is 2.6 years (SD = 1.9 years).

Stochastic model

We conducted a stochastic matrix analysis for Lincoln's sparrow. We incorporated stochasticity in several ways (**Table A4**), by varying different combinations of vital rates, by varying the amount of stochastic fluctuation and by varying the "base matrix" (the high or low adult-first-year survival ratio cases of **Figure A2**). We varied the amount of fluctuation by changing the standard deviation of the truncated random normal distribution from which the stochastic vital rates were selected. The high variability variant used a standard deviation of one quarter of the "mean" (with this "mean" set at the value of the original matrix entry [vital rate], a_{ij} under the deterministic analysis). The low variability variant used a standard deviation of one eighth of the mean. Under Variant 1 we subjected both reproductive arcs (F_{21} and F_{22}) to stochastic fluctuations with high variability (SD one quarter of mean) using the high ratio base matrix. Under Variant 2 we varied both survival arcs (P_{21} and P_{22}) with high variability (SD one quarter of mean), using the high ratio base matrix. Under Variant 3 we again varied survival but reduced the stochastic variability to one eighth of the mean, again using the high ratio matrix. Variant 4 analyzed the low ratio matrix with other parameters as in Variant 2. Each run consisted of 2,000 census intervals (years) beginning with a population size of 10,000 distributed

Table A3. Reproductive values (left eigenvector) for the high- and low-ratio cases. Reproductive values can be thought of as describing the "value" of a stage as a seed for population growth relative to that of the first (newborn or, in this case, egg) stage. The reproductive value of the first age class is always 1.0.

Stage	Description	High-ratio	Low-ratio
1	Eggs/first-year females	1.00	1.00
2	"Adult" females	3.57	2.47

according to the Stable Age Distribution (SAD) under the deterministic model. Beginning at the SAD helps avoid the effects of transient, non-equilibrium dynamics. The overall simulation consisted of 100 runs (each with 2,000 cycles). We calculated the stochastic growth rate, $log\ \lambda_s$, according to Eqn. 14.61 of Caswell (2000), after discarding the first 1,000 cycles in order to further avoid transient dynamics. We also calculated the number of runs that resulted in a population decline greater than 5% of the starting size.

The stochastic model (**Table A4**) produced two major results. First, high variability on survival under the high-ratio case had the greatest detrimental effect. For example, 38 of 100 runs led to extinctions with highly variable survival under Variant 1. The next greatest effect came from varying the fertility rates of all age classes using the high-ratio base matrix — 1 extinction and 37 declines. Low variability on survival eliminated extinctions using the high-ratio matrix and led to only 12 declines. Finally, even under high variability for survival the low ratio base matrix showed no extinctions and a modest 23 declines. The difference in the effects of which arc was most important is predictable largely from the elasticities. The single highest elasticity of λ was to "adult" survival under the high ratio case (e_{22} = 0.36). This detrimental effect of variability occurs despite the fact that the average vital rates remain the same as under the deterministic model — that is, the mean random selection should equal the deterministic matrix value. Why should stochasticity have a depressive effect even when the mean effect is neutral? This apparent paradox is due to the lognormal distribution of stochastic ending population sizes (Caswell 2000). The lognormal distribution has the property that the mean exceeds the median, which exceeds the mode. Any particular realization will therefore be most likely to end at a population size considerably lower than the initial population size. Second, the magnitude of stochastic fluctuation has a discernible effect on population dynamics (compare Variant 1 to Variant 3 in **Table A4**). These results indicate that populations of Lincoln's sparrow are vulnerable to stochastic fluctuations in survival (due, for example, to annual climatic change or to human disturbance), especially when the magnitude of fluctuations is high. Pfister (1998) showed that for a wide range of empirical life histories, high sensitivity or elasticity was negatively correlated with high rates of temporal variation. That is, most species appear to have responded to strong selection by having low variability for sensitive or

Table A4. Summary of four variants of stochastic projections for Lincoln's sparrow with N_0 = 10,000 individuals.

	Variant 1	Variant 2	Variant 3	Variant 4
Input factors:				
Affected cells	P_{21} and P_{22}	F_{11} and F_{12}	P_{21} and P_{22}	P_{21} and P_{22}
Base matrix	High-ratio	High-ratio	High-ratio	Low-ratio
S.D. of random normal distribution	1/4	1/4	1/8	1/4
Output values:				
Deterministic λ	1.003	1.003	1.003	1.006
# Extinctions / 100 trials	38	1	0	0
Mean extinction time	1,325	1,894	N/A	N/A
# Declines / # survived population	49/62	36/99	12/100	23/100
Mean ending population size	531,192	372,964	1.8×10^6	1.9×10^9
Standard deviation	3.6×10^6	1.1×10^6	9.2×10^6	1.6×10^6
Median ending population size	350	30,247	127,067	171,913
Log λ_s	-0.00441	0.00026	0.00128	0.00149
λ_s	0.9956	1.0003	1.0013	1.0015
% reduction in λ	0.73	0.27	0.17	0.44

elastic transitions in their life cycles. For Lincoln's sparrows, with stochasticity having the greatest impact on survival, the life history may not allow the kind of adjustment of risk load that may be possible in other species. Variable survival, especially in the first year, is likely to be the rule rather than the exception.

Potential refinements of the models

Clearly, the better the data on survival rates, the more accurate the resulting analysis. The most important "missing elements" in the life history for Lincoln's sparrows are for survival rates, which emerges as the vital rates to which λ is both most sensitive and most elastic. Data from natural populations on the range of variability in the vital rates would allow more realistic functions to model stochastic fluctuations. For example, time series based on actual temporal or spatial variability, would allow construction of a series of "stochastic" matrices that mirrored actual variation. One advantage of such a series would be the incorporation of observed correlations between variations in vital rates. Using observed correlations would improve on our "uncorrelated" assumption, by incorporating forces that we did not consider. Those forces may drive greater positive or negative correlation among life history traits. Other potential refinements include incorporating density-dependent effects. At present, the data appear insufficient to assess reasonable functions governing density dependence.

Summary of Major Conclusions from Matrix Projection Models

- Survival accounts for 78% of the total "possible" sensitivity in the high-ratio case (P_{22} = 0.59 vs. P_{21} = 0.18). Any absolute changes in survival rates will have major impacts on population dynamics. Survival accounts for slightly less (71%) of the total when first-year (P_{21} = 0.23) and "adult" (P_{22} = 0.5) survival are more similar. In both cases, however, survival is considerably more important than is fertility.

- Survival (P_{21} and P_{22}) account for 60.9% of the total elasticity, compared to the 39.1% accounted for by the fertilities under the high-ratio case. The relative importance of survival and fertility (52 vs. 47%) is more even in the low-ratio case. Nevertheless, in both cases proportional changes in first-year and "adult" survival will have a major impact on population dynamics.

- The reproductive value of "adult" females is moderately high (they are "worth" 3.6 eggs in the high ratio case and 2.5 eggs in the low-ratio case). Their reproductive value makes them possible buffers against the detrimental effects of variable conditions.

- Stochastic simulations echoed the elasticity analyses in emphasizing the importance of variation in survival to population dynamics, especially in the high-ratio case. In comparison to life histories of other vertebrates, Lincoln's sparrows appear slightly less vulnerable to environmental stochasticity (because of the buffering effect of a reservoir of "adult" females). Management should emphasize the collection of improved demographic data, particularly for first-year survival.

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